JOURNAL OF ECONOMIC ENTOMOLOGY

Official Organ American Association of Economic Entomologists

Vol. 40 October, 1947 No. 5

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JOURNAL OF ECONOMIC ENTOMOLOGY

Official Organ American Association of Economic Entomologists

Vol 40 October, 1947 No. 5

DDT Preparations to Control Certain Scale Insects On Citrus

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In a preliminary report (Ebeling 1945a) it was shown that the effectiveness, over a prolonged period, of an oil spray against the California red scale, *Aonidiella aurantii* (Mask.), on citrus trees is sometimes considerably increased by the addition of DDT[3] to the oil at the rate of 4 g. to 100 ml. of oil (4.7 weight per cent).[4] The increase in effectiveness was caused mainly by the residual effect of DDT in preventing the settling and development of the larvae (crawlers) born of those insects not killed by the spray. Five per cent kerosene containing 4.7 per cent of DDT was usually more effective than oil spray, but 3 per cent kerosene with the same concentration of DDT was less effective than oil spray. Two applications of the 3 per cent DDT-kerosene, the second following the first by about two months, proved to be a very effective control for red scale.

The experiments begun in 1945, the results of which are presented in this paper, were made in 14 orange and lemon orchards in 7 southern California counties. They were designed to provide information on the following phases of the problem: (1) increase in DDT concentration in the oil by the use of mutual solvents and the effect of this increased concentration on the insecticidal effectiveness of the spray; (2) the relation of time of application to effectiveness; (3) the difference in effectiveness between one application and two applications of DDT per year; (4) the effect of the addition of aluminum stearate to the kerosene solutions; and (5) the relationship of the use of kerosene sprays to fruit quality and water spot.[5]

MATERIALS AND APPLICATION.—The petroleum oils were of the following types: light medium spray oil, 56 per cent distilled at 636° F, viscosity 70 seconds Saybolt at 100° F, unsulfonated residue 90 per cent; mineral seal oil, 90 per cent distilled at 636° F, viscosity 47 seconds Saybolt at 100° F, unsulfonated residue 88 per cent; and kerosene, initial boiling point 360° F, end point 498° F, unsulfonated residue 59–97 per cent.

Technical grade DDT from various sources was sometimes dissolved in the oil at 60° C at the rate of 4 g. to 100 ml., but often the DDT was mixed with the oil in the field and this mixture was forced through the spray pump for 1 or 2 minutes. The violent agitation of the spray mixture and the increase in temperature of the DDT-petroleum solution as it passed through the spray pumps resulted in rapid and complete dissolving of the DDT in the petroleum and obviated the necessity for heating it. The other concentration at which the DDT was used during the past season was 8 g. to 100 ml. of petroleum. When this concentration of DDT was used it was necessary to add a mutual solvent to the petroleum. *Velsi-*

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[2] The writer wishes to acknowledge the assistance of Messrs. Gene Wood and H. G. Johnson, Laboratory Assistants at the Citrus Experiment Station.

[3] 2,2-bis (4-chlorophenyl)-1,1,1 trichloroethane.

[4] In this paper, as regards DDT, per cent refers to per cent by weight. A concentration of 4 g. of DDT to 100 ml. of kerosene is 4.7 per cent and a concentration of 8 grams to 100 ml. of petroleum is 9.4 per cent. For light medium spray oil the amounts of DDT added to 100 ml. were, respectively, 4.35 g. and 8.7 g. to obtain 4.7 per cent and 9.4 per cent DDT in the oil.

[5] Water spot is a malady occurring on navel oranges after prolonged periods of rain during the period when the fruit is mature, usually January and February. The fruit imbibes water through the cuticle, which causes a swelling in the affected area, and a cracking of the cuticle. Later the affected portion becomes depressed and discolored, and rot-producing organisms may enter the cracks in the cuticle and cause a rotting of the fruit. The incidence of water spot is usually greatly increased if the fruit is sprayed with light medium spray oil, which is the usual spray treatment.

col AR-60[6] and tetralin[7] were used as mutual solvents in nearly all the experiments and they proved to be about equally effective. One of their favorable characteristics is that they do not appreciably affect the oil-depositing properties of the spray. Ten per cent by volume of mutual solvent was used in the petroleum if it was desired to store the DDT-petroleum solution for some time before using. Low night temperatures, especially, make a large quantity of mutual solvent necessary in order to keep the DDT in solution. If the DDT is to be put into solution in the spray rig, however, according to the method mentioned above, and the spray is to be used immediately, the concentration of mutual solvent may be reduced to 5 per cent.

In some treatments aluminum stearate at 1 g. to 100 ml. was added to the kerosene solutions to prevent or retard the penetration of the kerosene into the tree surface (Ebeling, 1945b). When aluminum stearate was used, the DDT-kerosene solution was heated to about 70° C instead of 60° C. The aluminum stearate is in the form of a powder. This was stirred into the DDT-kerosene solution before heating. The mixture was then periodically stirred while heating, to insure that the aluminum stearate be well dispersed before gell formation took place. At about 70° C a jelling of the DDT-aluminum stearate-kerosene solution takes place. It would be fortunate if the jelly-like character of the solution could be maintained, because of the consequent increase in kerosene deposit by the spray. The solution gradually becomes thinner, however, until the jelly-like consistency is entirely lost. The tendency of the kerosene to penetrate plant tissue more slowly, however, is retained. The jelly-like character of the solution can be prolonged by the addition of small amounts of naphthenic acid to the solution while it is being prepared, but the naphthenic acid "tightens" the emulsion and the desired goal of increasing kerosene deposit is not attained.

In the preparation of aqueous suspensions of DDT, a powder containing 40 per cent DDT was used. Five pounds of this powder was added to the spray tank when the tank was beginning to be filled with water. With the agitator running, a pound of *DDT depositor*[8] was added, and one quart of kerosene. The addition of the *DDT depositor* and the kerosene resulted in a heavy and uniform deposit of DDT on the trees.

When the tank-mixture spray oil or kerosene were used, blood albumin spreader at 4 ounces to 100 gallons of spray was added, except in a few plots where otherwise stated.

In some of the plots sprayed with DDT-kerosene solution or with wettable DDT powder , half of the plot was resprayed, usually about two months after the first treatment. In each plot, then, a comparison could be made in the results of 1 treatment and the results of 2 treatments of the same material. Sometimes the second treatment was made with only half the gallonage per tree used in the first treatment.

The sprays were applied by means of a 400 gallons capacity power sprayer with 550 pounds pressure and using 8/64 inch disks in the nozzles. The applications were made in accordance with good commercial practice.

Experiments were made in 8 Navel orange orchards, 3 Valencia orange orchards, and 3 lemon orchards. One or more experiments were made in each of 7 southern California counties.

METHOD OF ANALYSIS OF DDT.—The estimation of the quantity of DDT left on the foliage by the sprays was done by Dr. Francis A. Gunther by means of the quantitative dehydrohalogenation method which he devised (Gunther, 1945). This method could not be used successfully when sulfur was present, a disadvantage which was more recently ovrecome by means of a new procedure (Baier *et al.*, 1946).

METHOD OF EVALUATING TREATMENTS.—In the experiments with red scale,[9] the mean number of live adult female insects per fruit was determined for each of 10 trees in each plot before treatment. The counts were nearly always made on 10 fruits per quadrant, selected at random. Thus 40 fruits per tree were sampled.

In the case of lemon trees, the fruits

[6] Methyl naphthalenes.
[7] Tetra hydra naphthalenes.

[8] Furnished through the courtesy of Colloidal Products Corporation, San Francisco, California.

[9] Of 14 orchards in which experiments were made, only one was infested with yellow scale. A different method for the estimate of populations had to be employed for the yellow scale and this method is described later in the discussion of the yellow scale experiment.

on which the counts were made were those which were sufficiently large to be picked, but not sufficiently mature to be classed in the "yellow" grade. Since the longer the fruit stays on the tree the greater the population of red scale able to develop on it, the estimates of population must be made on fruits within reasonably narrow limits of size and age.

When making counts on oranges, any fruits of the current season may be used because the fruits all started their development within a reasonably limited period in the spring of the year. Valencia oranges begin blooming later than Navels, so that experiments made on Valencia orange trees as early as the first of July may have fruit so young that red scale on the fruit may not have had sufficient time to become mature. In that event immature scales may have to be counted in the pre-treatment counts. If the ripe fruit of the previous year's crop has not yet been picked, the pre-treatment counts may be made on this fruit.

In some orchards the percentage of red scale-infested fruit within reach of the observer was determined, rather than the number of adult female scales per fruit. This comparatively rapid method was employed because of the scarcity of help due to war-time conditions. Nevertheless the method served to provide an estimate of pre-treatment variance between trees and between plots.

The evaluation of treatments was made entirely by estimates of population density immediately before treatment and at various periods after treatment. The period required before an evaluation of the effectiveness of the treatment could be made depended on how rapidly the trees became sufficiently reinfested to make possible an adequate estimate of population differences in the various plots.

The sampling of 40 fruits per tree and 10 trees per plot was based on an extensive statistical study of the red scale population in two lemon orchards and an orange orchard.[10] It was found in this study that even in a relatively light infestation of red scale, there was little advantage in sampling a greater number of fruits per tree. Also 10 trees per plot were found to be adequate for the purposes of the field experiments which were contemplated.

To simplify the presentation of data, only the average number of scales per fruit per plot is shown in the tables. In the original statistical study of the problem, however, it was shown by analysis of variance that differences in population density as small as 5 per cent could be shown to be significant when sampling was done in accordance with the method employed in the experiments recorded in this paper.

In the tables it will be seen that after stating the number of scales per fruit after treatment, determined according to the aforementioned method, another column of figures is given with the heading "Corrected Relative Infestation" (Oil Spray=100). This is to facilitate the comparison of the effectiveness of the various treatments with oil spray used at the usual commercial dosage of 1.75 per cent. Furthermore, in this column of figures corrections are made for the original differences in infestation in the plots at the time of treatment. When computing the corrected relative post-treatment infestation in any plot B when the post-treatment infestation in the plot sprayed with oil alone, designated as plot A, is given the value 100, the pre-treatment and post-treatment counts in plot A are designated, respectively, as a and a', the pre-treatment and post-treatment counts in plot B are designated, respectively, as b and b', and x is the corrected relative infestation:

Then,

$$\frac{100\ ab'}{a'b} = x.$$

Results with DDT-petroleum Solutions Used Against Red Scale. Spray Oil.—Tables 1 to 4 inclusive, showing the results of 8 experiments, are arranged in chronological order so as to facilitate the study of the influence of season on the effectiveness of the treatments. Table 1 shows the results of 2 experiments, one begun on April 25, 1945, and the other begun on June 28, 1945. If some of the plots were resprayed in the two-treatment program with DDT-kerosene, the tables were nevertheless arranged in accordance with the date of the first treatments. In

[10] Ebeling, W. and C. O. Persing. 1945. Evaluation of insecticides used against red scale by estimates of population densities. Manuscript on file at the Division of Entomology, University of California, Los Angeles.

table 2 the experiments were begun in the months of July and August, in table 3 the experiment was begun in the month of August, and in table 4 the experiments were begun in the months of September and November.

The main effect of the DDT in either spray oil or kerosene is its effect as a residue in inhibiting the settling of red scale crawlers or inhibiting the development of the few crawlers that manage to settle on the tree surface and pass the whitecap

Table 1.—Results with DDT dissolved in light medium spray oil and kerosene and used against the California red scale. First applications made in April and June, 1945.

Treatment Number	Treatment[1]	Initial External Deposit of DDT Mg./sq. cm.	Scales per Fruit Before Treatment	Scales per Fruit After Treatment	Corrected Relative Infestation (Oil Spray = 100)
	Experiment 1. Lemons, Upland. Sprayed Apr. 25, 1945; counted Aug. 21, 1945				
1	Oil, 1.75%	—	2.0	1.2	100
2	Oil, 1.75%; DDT, 4.7%	1.8	2.3	1.1	82
3	Oil with 10% tetralin, 1.75%; DDT, 9.4%	4.9	2.4	0.7	49
4	Kerosene, 3%	—	2.3	4.4	334
5	Kerosene, 3%; DDT, 4.7%	5.8	2.3	3.1	235
6	Kerosene with 10% tetralin, 3%; DDT, 9.4%	7.6	2.4	2.3	150
7	Same as treatment 6, but retreated 6/27/45	8.3	2.5	0.5	33
	Experiment 2. Valencia oranges, Highland. Sprayed June 28, 1945; Counted Jan. 16, 1946				
1	Oil, 1.75%	—	1.7	4.4	100
2	Oil, 1.75%; DDT, 4.7%	2.9	2.3	2.5	42
3	Oil+10% *Velsicol AR-60*, 1.75%; DDT 9.4%	5.0	3.1	1.8	22
4	Mineral Seal+10% *Velsicol AR-60*, 1.75%; DDT, 9.4%	3.7	3.7	3.0	31
5	Kerosene, 3%; DDT, 4.7%	9.4	2.3	8.8	148
6	Same as 5, but retreated 8/13/45	—	1.2	1.4	45
7	Kerosene+10% tetralin, 3%; DDT 9.4%	13.9	3.1	3.0	37
8	Same as 7, but retreated 8/13/45	—	4.6	0.9	8

[1] Blood albumin spreader at 4 ounces to 100 gallons of spray was used in all treatments. The concentration of DDT is expressed in weight per cent.

Table 2.—Results with DDT dissolved in light medium spray oil and kerosene and used against the California red scale. First applications made in July, 1945.

Treatment Number	Treatment[1]	Initial External Deposit of DDT Mg./sq. cm.	Per Cent of Fruit Infested Before Treatment	Number of Scales per Fruit After Treatment	Corrected Relative Infestation (Oil Spray = 100)	Number of Scales per Frut 10/11/46
	Experiment 1. Valencia Oranges, Escondido. Sprayed July 13, 1945; counted Dec. 3, 1945					
1	Oil, 1.67%	—	26.2	13.6	100	
2	Oil, 1.67%; DDT 4.7%	4.3	20.4	4.4	41	
3	Oil+10% tetralin, 1.67%; DDT 9.4%	7.2	29.5	9.6	63	
4	Kerosene, 3%; DDT, 4.7%	4.1	13.4	7.4	107	
5	Same as treatment 4, but repeated 9/27/45	4.1–8.4	16.0	1.6	19	
6	Kerosene+10% tetralin 13%; DDT, 9.4%	11.6	8.4	3.4	78	
7	Same as treatment 6, but repeated 9/27/46	11.6–19.6	10.4	1.0	18	
8	Kerosene+10% *Velsicol AR-60*, 3%; DDT 9.4%	12.6	14.4	3.6	48	
9	Same as treatment 8 but repeated 9/27/46	12.6–18.6	16.0	1.2	14	
	Experiment 2. Navel Oranges, Redlands. Sprayed Aug. 6, 1945; counted Nov. 5, 1945					
1	Oil, 1.67%	—	27.3	14.9	100	—
2	Oil+10% tetralin, 1.67%; DDT, 9.4%	13.1	43.8	19.2	80	66.9[2]
3	Kerosene+5%[3] tetralin and 0.1% aluminum stearate 3%; DDT 9.4%	25.9	27.0	10.4	80	—
4	Same as treatment 3, but repeated 10/10/45	25.9–30.2	27.0	—	—	0.9
5	Kerosene+10% tetralin, 3%; DDT 9.4%	36.7	25.8	3.3	23	—
6	Same as treatment 5, but repeated 10/10/45	36.7–34.4	25.8	—	—	0.4
7	Kerosene+10% *Velsicol AR-60*, 3%; DDT 9.4%	36.6	21.5	3.4	29	—
8	Same as treatment 7, but repeated 10/10/45	36.6–40.1	21.5	—	—	4.3
9	Kerosene+5% tetralin, 3%; DDT 9.4%	30.6	19.0	4.9	47	—
10	Same as treatment 9 but repeated 10/10/45	30.6–35.7	19.0	—	—	3.2

[1] Blood albumin spreader at 4 ounces to 100 gallons of spray was used in all treatments. The concentration of DDT is expressed in weight per cent.

[2] The orchard became so rapidly reinfested that it had to be resprayed soon after the counts made Nov. 5, 1945. The twice-sprayed plots did not have to be resprayed however, and 5 trees in plot 2 were not retreated. Counts were made on these 5 trees, as well as in plots 4, 6, 8, and 10 on Oct. 11, 1946.

[3] When 5 per cent of mutual solvent was used, the DDT was dissolved in the orchard by forcing the DDT-mutual solvent-kerosene mixture through the spray pumps for 2 minutes.

stage. Lindgren *et al.* (1944) found this "residual effect" of the DDT to be quite prominent as long as 70 days after treatment.

Since a greater number of red scale crawlers are born during the warmer periods of the year, the increase in the April 25, 1945, although the addition of DDT to the light medium oil substantially increased the effectiveness of the spray, the DDT-kerosene treatments were the least effective of all the treatments made throughout the season. It should be borne in mind, however, that the DDT deposits

Table 3.—Results with DDT dissolved in light medium spray oil or kerosene and used against the California red scale. First applications in August, 1945.

Treatment Number	Treatment[1]	Initial External Deposit of DDT Mg/sq. cm.	Infested Fruit per Tree Before Treatment	Number of Treatments	Number of Scales[2] per Tree 1/25/46	Number of Scales[2] per Tree 10/25/46	Corrected Relative Infestation (Oil Spray = 100)
1	Oil, 1.67%	—	5.6	1	18.3	74.3	100.0
2	Oil, 1.67%, DDT 4.7%	6.5	5.2	1	10.4	39.4	57.3
3	Oil+10% tetralin, 1.67%; DDT 9.4%	10.0	4.6	1	32.2	62.0	101.6
4	Oil+10% *Velsicol AR-60*, =16%; DDT, 9.4%	8.7	6.9	1	28.7	117.7	128.6
		11.9	4.9	1	114.8	258.4	315.1
5	Kerosene 8%, DDT, 4.7%			2	46.3	21.2	32.6
				1	62.5	55.7	93.3
6	Kerosene+1% aluminum stearate, 3% DDT, 4.7%; calcium caseinate spreader, 1 lb.–100; $CaCl_2$, 1 lb.–100 gals.	15.8	4.5	2	18.7	2.4	4.2
				1	20.6	6.5	10.9
7	Kerosene+1% aluminum stearate and 10% tetralin, 3%; DDT, 18.8%[3]	52.9	4.5	2	4.3	0.0	0.0
				1	16.6	2.6	4.1
8	Kerosene+1% aluminum stearate and 5%[4] tetralin, 3%; DDT, 9.4%	26.5	4.8	2	2.3	0.7	1.1
				1	6.4	0.2	0.5
9	Kerosene+1% aluminum stearate and 5% tetralin, 3%; recrystallized DDT, 9.4%	23.5	2.8	2	5.1	0.1	0.3
				1	7.4	5.3	12.1
10	Kerosene+5% tetralin, 3%; recrystallized DDT, 9.4%	26.7	3.3	2	5.7	1.4	3.2
				1	16.5	7.6	14.3
11	Kerosene+5% tetralin, 3%; DDT, 9.4%	20.2	4.0	2	4.8	0.6	1.1
				1	11.2	5.6	14.6
12	Kerosene+5% *Velsicol AR-60*, 3%; DDT, 9.4%	23.8	2.9	2	2.3	0.3	0.8
				1	89.4	64.6	86.9
13	Wettable 40% DDT powder, 5 lbs.–100 gals.; 1 lb. *DDT Depositor*[5] and 1 quart kerosene to 100 gals.	21.1	3.1	2	68.1	8.5	11.4
14	Proprietary light medium emulsive oil, 1.75%	—	3.1	1	9.3	31.4	76.4

[1] The first applications of spray were made on August 10 and 11, 1945. The second applications, in the two-treatments program were made on October 12, 1945. In each of the plots where the kerosene was used, half of the trees were resprayed about 2 months after the first treatment. Blood albumin spreader at 4 ounces to 100 gallons of spray was used in all treatments except treatment 6, in which calcium caseinate spreader and calcium chloride were added to the spray in an effort to increase the deposit of kerosene over that which was deposited in treatment 5.

[2] Because of the small numbers of scales per fruit in some of the plots, the number of scales per tree, that is, the number on 40 fruits, was presented in the chart.

[3] In this treatment, 2 pounds of DDT were added in the orchard to each 3 gallons of kerosene in addition to the 9.4 weight per cent already dissolved in the kerosene. It is probable that in forcing this mixture through the pumps for 2 minutes, practically all the DDT was dissolved in the kerosene. The kerosene would thus contain 18.8 weight per cent of DDT.

[4] Wherever 5 per cent by volume of mutual solvent was used, as in plots 8 to 12, inclusive, the DDT was added to the mutual solvent-kerosene solution immediately before pouring the solution into the spray tank. The DDT was dissolved by forcing the mixture through the spray pumps for 2 minutes before adding the water to the spray tank.

[5] To increase the deposit of DDT, 1 pound of a proprietary product called "DDT Depositor" and 1 quart of kerosene were added to 100 gallons of spray. The "DDT Depositor" was furnished through the courtesy of Colloidal Products Corporation, San Francisco, California.

long-term effectiveness of a spray by the addition of DDT might logically be expected to be greater during those periods. On the other hand it must be taken into consideration that the decomposition of the DDT takes place at a more rapid rate during these warmer periods of the year, thus detracting, at least to some extent, from the advantages of treatment during a period when reproduction is rapid and the life cycle of the scale is short.

An inspection of the tables will reveal that in experiment 1, table 1, applied on were also light compared with the deposits in later treatments. In the latest experiment, applied November 21, 1945, (Table 4, experiment 3) the results of the DDT-kerosene sprays were again relatively poor, considering that two applications of each treatment were made. Here the DDT deposits were as high as in some of the experiments made during the summer in which much better results were obtained. These results tend to substantiate the conclusion drawn from the field work of the previous season (Ebeling,

1945a), that DDT added to petroleum fractions attains its greatest effectiveness during the warmer periods of the year.

DDT added to light medium spray oil did not always increase the effectiveness of the spray in proportion to the concentration of DDT in the spray. In the tables it will be noted that in two of the experiments in which both 4.7 per cent and 9.4 per cent of DDT was used (Table 2, experiment 1, and Table 3), better results were obtained with 4.7 per cent DDT in spray oil than with 9.4 per cent. In the experiment shown in table 3, in fact, the oil spray with 9.4 per cent DDT was less effective, on the basis of counts made 14 months after treatment, than the same dosage of oil spray without DDT. When the results of all experiments in which both 4.7 per cent and 9.4 per cent of DDT was used are averaged, however, the following figures, representing the relative effectiveness of the treatments, are obtained: light medium spray oil alone, 100; light medium spray oil with 4.7 per cent DDT, 63.9; light medium oil with 9.4 per cent DDT, 52.8. It is not known why the sprays with the higher concentration of DDT were the least effective in the experiments shown in

Table 4.—Results with DDT dissolved in light medium oil and kerosene and used against the California red scale. First applications made in September and November, 1945.

Treatment Number	Treatment[1]	Initial External Deposit of DDT Mg./sq. cm.	Scales per Fruit Before Treatment	Scales per Fruit After Treatment	Corrected Relative Infestation (Oil Spray = 100)
	Experiment 1. Valencia oranges, San Fernando. Sprayed Sept. 10, 1945; counted Oct. 2, 1946				
1	Oil, 1.67%	—	1.7	18.1	100
2	Oil, 1.67% DDT, 4.7%	1.9	2.5	24.8	93
3	Oil+10% tetralin, 1.67%; DDT, 9.4%	6.0	2.3	9.3	38
4	Kerosene+10% tetralin 3%, DDT 9.4%	19.3	2.7	31.0	108
5	Same as 4, but retreated 11/16/45	19.3–22.7	2.7	1.2	4
6	Wettable 40% DDT powder, 5 lbs.–100 gals. Retreated 11/16/45	17.4–23.2	2.9	186.9	60
	Experiment 2. Lemons, Rialto. Sprayed Sept. 12, 1945; counted Oct. 8, 1946				
1	Oil, 1.75%	—	1.2	59.6	100.0
2	Kerosene+10% tetralin, 3%; DDT, 9.4%	16.3	1.0	1[2] 15.0	26.1
				2 5.5	11.1
3	Kerosene+10% *Velsicol AR-60*, 3%; DDT, 9.4%	17.2	1.1	1 10.2	18.7
				2 3.0	5.5
4	Kerosene, 5%; DDT 4.7%	9.6	0.7	1 6.1	17.5
				2 1.5	4.3
5	Kerosene+1% aluminum stearate, 5%; DDT 4.7%	16.3	1.4	1 9.7	14.0
				2 0.8	1.2
6	10 lbs. wettable 50% DDT–50% sulfur mixture, 1 lb. DDT. Depositor, 1 qt. kerosene, of 100 gals. spray	—[3]	1.5	1 195.7	262.7
				2 163.4	219.3
	Experiment 3. Navel Oranges, La Verne. Sprayed Nov. 21, 1945; counted Oct. 7, 1946				
1	Oil, 1.75%	—	8.8	3.2	100
2	Oil, 1.75%; DDT 4.7%	3.1	8.5	2.1	68
3	Oil+10% *Velsicol AR-60*, 1.75%; DDT, 9.4%	7.2	9.4	1.0	29
4	Kerosene+10% APS-194, 3%; DDT, 9.4%. Retreated 12/20/46	18.3–17.2	12.6	1.8	39
5	Kerosene+10% tetralin, 3%; DDT, 9.4%. Retreated 12/20/46	21.3–24.6	8.0	0.4	14
6	Di-2-ethyl hexyl phthalate, 0.25%; DDT, 30%	10.8	9.1	22.6	683
7	Di-2-ethyl hexyl phthalate, 0.5%; DDT, 30%	6.2	7.2	4.3	164

[1] Blood albumin spreader at 4 ounces to 100 gallons of spray was used in all treatments. The concentration of DDT is expressed in weight per cent.

[2] The figures in this column show the number of treatments. In the plots sprayed with kerosene, half of each plot was resprayed November 5, 1946.

[3] The determination of the amount of DDT deposited was not possible in the plot with the method of residue analysis employed, because of the presence of sulfur.

table 3. If the data in this table are not included, then the average for the remaining five experiments in which the two concentrations of DDT were used in light medium spray oil are as follows: oil spray alone, 100; oil with 4.7 per cent DDT, 65.3; oil spray with 9.4 per cent DDT, 40.3. Thus at various periods after treatment, varying from 4 to 13 months, there was an average of about 2.5 times as many scales in the plots sprayed with light medium oil alone as in the plots sprayed with light medium oil with 9.4 per cent DDT.

Kerosene.—Three per cent kerosene has practically no insecticidal effect against the California red scale, and the oily residue left by the spray disappears within a day or two. Therefore in order to be effective, any toxicant added to the kerosene would have to result in an extremely high mortality of the scales or have a prolonged residual effect against the crawlers born of those adult scales not succumbing to the treatment. Kerosene-mutual solvent solutions containing 9.4 per cent DDT have sometimes been found to cause a considerable mortality of red scale on the leaves and fruit of citrus trees, but not on the rough bark of the branches. As years of previous experience has shown, however, such mortality as has been obtained would of itself have practically no long-term effect on a red scale population.

A considerable residual effect of the DDT-kerosene solutions used at 3 per cent was usually shown in the experiments the results of which are presented in this paper. An exception can be seen in table 1, experiment 1, in treatments applied April 25, 1945, in which the DDT-kerosene was in no case as effective as oil spray except in the plot in which a second spray was applied two months after the first. Here the prolonged residual effect of the DDT was sufficient to reduce the red scale population to only one third that which was found in the plot sprayed with 1.75 per cent oil spray when an estimate of comparative population densities was made in the various plots four months after treatment. The relative ineffectiveness of the DDT-kerosene treatments, in this particular experiment, however, may at least in part be explained by the low deposit of DDT as indicated by the analysis of DDT on the surface of the foliage (Table 1).

With the exception (Table 3, treatment 6) one spray of 3 per cent kerosene containing 4.7 per cent DDT in the kerosene, did not result in as good a control of red scale as the regular oil spray treatment. On the other hand, 3 per cent kerosene containing 9.4 per cent DDT in the kerosene invariably resulted in better control of red scale, on the basis of counts made from 4 to 14 months after treatment, than oil spray.

By far the most effective in controlling the red scale were the two-treatments programs with 3 per cent DDT-kerosene. In these two-treatments programs, both 4.7 per cent and 9.4 per cent DDT in the kerosene resulted in better control than oil spray, although the treatments in which the higher concentration of DDT was used were by far the most effective (see fig. 1). The most outstanding results were those shown in table 3, in which from 0.3 per cent to 3.2 per cent as many adult female red scale per tree were found in the plots treated with 2 sprays of 3 per cent kerosene containing 9.4 per cent DDT as in the plot sprayed with 1.67 per cent light medium oil.

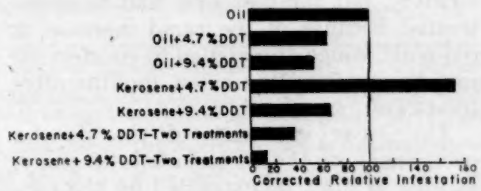

FIG. 1.—Average corrected relative infestation of adult female red scale in six experiments in which 1.75 per cent DDT-spray oil and 3 per cent DDT-kerosene were compared with the standard red scale treatment of 1.75 per cent light medium oil spray.

Results approaching those obtained with 2 treatments of 3 per cent DDT-kerosene can be attained by applying 1 treatment, but with a very heavy deposit of DDT. In the second experiment presented in table 2, a plot was sprayed with 3 per cent DDT-tetralin-kerosene solution, the kerosene containing 1 per cent aluminum stearate. The agitation was poor, resulting in the kerosene to a large extent floating on top of the water until the tank was about half empty. Then the concentration of kerosene rapidly became

very high. When kerosene containing aluminum stearate is used at a high concentration a partial inversion of emulsion, resulting in very heavy deposit of kerosene, occurs. In the block of trees sprayed with the tank of spray in question, the last 6 trees received such a heavy deposit of DDT-kerosene that they became distinctly white in appearance. The deposit of DDT was unfortunately not determined. Fifteen months after treatment, however, there was only 0.24 scale per fruit on these six trees, compared with 66.9 scales per fruit on the trees sprayed with 1.75 per cent light medium oil containing 9.4 per cent DDT.

Wettable DDT Powder.—Although 40 per cent wettable DDT powder used at 5 pounds to 100 gallons of spray deposited as much DDT on the tree surface as the 3 per cent DDT-kerosene sprays, it was far less efficient in controlling the red scale, as can be seen from an inspection of table 3 and table 4, experiment 1. A mixture of half DDT and half sulfur made wettable with calcium caseinate (table 4, experiment 2, treatment 6), was even less effective than the wettable DDT powder. The same mixture was used in the experiment presented in table 1 (experiment 2), but the plot soon had to be retreated because of the rapid increase in red scale, which threatened to severely injure the trees within a few months after treatment.

The lesser efficiency of the powder compared with the kerosene solution may, at least in part, be explained by the considerable insecticidal value which the kerosene solution has, but which is lacking when the powder is used. The writer has observed as high as 82.3 per cent kill of adult female red scale on the leaves of orange trees, sprayed with 3 per cent kerosene containing 9.4 per cent DDT, and as Lindgren *et al.* (1944) have shown, the mortality of younger stages is much greater. A replication of this mortality in the second spray, in addition to the prolonged residual effect of the 2-spray program, usually results in an extremely high degree of red scale control when the DDT-kerosene treatments are compared with the usual commercial oil spray treatment.

OBSERVATIONS ON DDT-KEROSENE TREATED TREES AT LONG PERIODS AFTER TREATMENT.—In the experiment presented in table 3 it will be noted that the plots sprayed with DDT-kerosene, with the exception of treatment 5, had much fewer scales per tree on October 25, 1946, than they had on January 25, 1946. The counts made on January 25, 1946, were made on fruit which was on the trees at the time the trees were sprayed. The counts made on October 25, 1946, were made on the next crop of fruit, which was not on the trees at the time the treatments were made. This indicates that the longer the period between treatment and the estimates of population density, the greater the relative superiority of the DDT-kerosene spray.

When counts are made on the DDT-kerosene sprayed fruits, many scales of the generation which survived the treatment are counted. On the other hand, on the oil-sprayed fruits, the great majority of these insects are killed. Only in the counts made on the next crop of fruit are differences found which reflect correctly the long-term effectiveness of the DDT.

REDUCED VOLUME OF SPRAY PER TREE IN THE TWO TREATMENTS PROGRAM.—Inspection of trees sprayed with 3 per cent DDT-kerosene revealed the fact that the parts of the tree protected from the direct rays of the sun retain a discernible residue long after the residue has disappeared from the exterior of the tree. The DDT deposited on the branches, green twigs, undersides of leaves, and the portions of the fruits facing the interior of the tree is protected from rapid decomposition, and consequently retains its ability to prevent the establishment and development of the crawlers. The possibility was thus suggested that in the second spray in the two-treatments program, a reduced gallonage of spray applied to the exterior of the tree, possibly with some kind of mechanical or rapidly manipulated equipment, might be successfully used. The interior of the tree would have the prolonged residual protection against red scale crawlers of the DDT that has been protected from excessive light and heat. The parts of the tree most exposed to light, and hence the parts where red scale accumulates most rapidly, for the crawlers are positively phototropic, constitute the surfaces where the DDT decomposes most rapidly. These exposed parts of the tree could be given a second deposit of DDT very rapidly and rela-

tively inexpensively by applying reduced gallonages of spray per tree by mechanical means of application which are now available, or by employing spray guns adapted for rapid application of spray to the periphery of the tree.

In table 5 the results of 2 experiments with reduced gallonages of spray per tree are tabulated. In experiment 1 the spray was applied by means of a "broom rig," made with 50 per cent gallonage (table 5, experiment 2, treatments 4 and 5), the results were less satisfactory. When 9.4 per cent DDT was used, the 2 half-gallonage treatments were only slightly better than one spray with a thorough coverage and were much inferior to the 2 full-gallonage treatments. Too much of the tree was left without a protective covering of DDT when 2 half-gallonage

Table 5.—Results with the two-treatments program when one or both treatments are made with 50 per cent of the normal gallonage of spray per tree.

Treatment Number	Treatment[1]	Number of Scales per Fruit Before Treatment	Number of Scales per Fruit After Treatment	Corrected Relative Infestation (Oil Spray=100)
	Experiment 1. Navel oranges, La Verne. Sprayed Aug. 27, 1945; counted Oct. 12, 1946			
1	Oil, 1.75%	4.6	20.8	100
2	Kerosene+5%[2] tetralin, 3%; DDT, 9.4%; retreated 10/7/45	4.2	4.1	22
3	Kerosene+5% tetralin, 3%; DDT, 9.4%; retreated with 50% gallonage[3] 10/7/45	4.1	5.4	29
	Experiment 2. Valencia oranges, Westminster. Sprayed Aug. 24, 1945; counted Oct. 11, 1946			
1	Oil, 1.67%	0.14	3.7	100
2	Kerosene+10% tetralin, 3%; DDT, 9.4%	0.17	2.1	47
3	Same as 2, but retreated 10/25/45	0.12	0.4	13
4	Kerosene+5% tetralin, 3%; DDT, 9.4%; 50%[4] of normal gallonage. Retreated 10/25/45	0.17	1.6	36
5	Kerosene, 3%; DDT, 4.7%; 50%[4] of normal gallonage. Retreated 10/25/45	0.27	10.2	143

[1] Blood albumin spreader at 4 ounces to 100 gallons of spray was used in all treatments. The concentrations of DDT are expressed in weight per cent.

[2] When 5 per cent of mutual solvent was used, the DDT was added to the mutual solvent-kerosene solution immediately before pouring the solution into the spray tank. The DDT was dissolved by forcing the mixture through the spray pumps for 2 minutes before adding the water to the spray tank.

[3] The second treatment was mechanically applied by means of a "boom sprayer." Only about half of the normal gallonage per tree was applied. See explanation in text.

[4] Both treatments were applied by means of "broom guns," using approximately 50 per cent of the normal gallonage per tree. See explanation in text.

which mechanically applied the spray while the spray rig was being driven midway between two rows of trees. In experiment 2 the spray was applied by means of "boom guns." The man applying the spray sat on the spray rig and sprayed with an up and down motion of the gun, while the spray rig moved continuously, in low gear, at a slow, constant speed.

It will be seen in table 5 experiment 1, that when the first treatment was a thorough spray applied in the conventional manner and the second treatment was mechanically applied with the "boom sprayer," using only half the normal gallonage per tree, the results were almost as good as when the second treatment was also a thorough spray applied by hand. When both treatments were sprays were used. The portions of the tree missed by the spray in the first treatment are likely to be the portions missed by the second treatment. This difficulty could be partly obviated by driving the spray rig in opposite directions in the 2 treatments, but in many orchards, as was the case in the orchard in question, this can not be done because of the spacing of the trees, the course of permenent irrigation furrows, or for other reasons.

As can be seen in table 5, experiment 2, treatment 5, the reduction of DDT concentration from 9.4 to 4.7 per cent resulted in a great reduction in the effectiveness of the two-treatment program as carried out in this experiment. The 9.4 per cent DDT spray not only results in longer residual effect, but also kills a

greater per cent of the red scale on the tree at the time of treatment.

RELATION OF ALUMINUM STEARATE TO INSECTICIDAL EFFECTIVENESS.—The writer has shown (Ebeling 1945b) that aluminum stearate added to a DDT-kerosene solution will prevent or greatly retard the penetration of kerosene into leaves or bark of citrus trees. The result is that the kerosene volatilizes on the tree surface and deposits DDT on the surface instead of rapidly carrying it into the plant tissues, as happens when aluminum stearate is not added. On leaves and branches removed from the tree and taken to the laboratory, the increase in surface deposit of DDT when aluminum stearate is added to the solution is very great, but Gunther *et al.* (1947) have shown that in the case of leaves remaining on the tree, while the DDT-kerosene quickly enters the leaves, it also slowly migrates back to the surface and volatilizes there, depositing the DDT on the surface. Thus in one experiment, while a 3 per cent DDT-aluminum stearate-kerosene solution left about twice as much DDT on the leaf surface immediately after treatment, no difference in surface deposit could be found 24 hours after treatment (Gunther *et al.*, 1947). Possibly a co-distillation process takes place by which kerosene is carried from the foliage by escaping water vapor.

Despite the reappearance of the DDT on the surface of the foliage, the addition of aluminum stearate to the DDT-kerosene solution has been found to increase effectiveness of the spray. Possibly the process by which the DDT reappears on the leaf surface does not operate to the same extent on the other parts of the tree.

In table 3 in treatments 8 and 9, in which 1 per cent aluminum stearate was added to a 9.4 per cent DDT-kerosene solution the population of red scale 14 months after treatment was considerably less than in plots 10, 11, and 12, in which the same concentration of DDT was used, but without aluminum stearate. In the 2 plots containing the aluminum stearate the corrected relative infestation (compared with oil spray = 100) averaged 2.3 for the single treatments and 0.7 for the double treatments. In the three plots sprayed with the same concentration of DDT in the kerosene, but without aluminum stearate, the average corrected relative infestation was, for the single treatments, 13.7, and for the double treatments, 1.7. A difference in the same direction is shown in table 4, experiment 3, treatments 4 and 5.

DDT FOR YELLOW SCALE CONTROL.—The yellow scale, *Aonidiella citrina* (Coq.) is morphologically almost identical with the California red scale, and biologically it is very similar. It might be expected to respond in a similar manner to an insecticide treatment. This has not proven to be the case, however, in the present experiments. Only one experiment was made with yellow scale, yet since the results were at such wide variance with those which were obtained in the red scale experiments, the data presented may be considered to be at least suggestive.

An experiment was made near Exeter in Tulare County, California, in a Navel orange orchard infested with yellow scale. The first sprays were applied on September 21, 1945. On October 4, 1946, an estimate of population density was made. The methods used for the estimation of population density were different than those used in the red scale experiments, for while the red scale is quite uniformly distributed, the yellow scale occurs in a spotty type of distribution. Fruits may be extremely heavily infested in a small area of the tree while a few feet away the fruit may be entirely free of scale.

In making the pre-treatment estimate of population density differences, it was found that the fruit, being small and immature, was too lightly infested to be used in the sampling. The yellow scale was found in patches on the foliage, usually on the northeast quadrant of the tree and near the ground. The trees were graded as to relative degree of infestation based on observations made by the worker as he slowly walked around the north halves of the trees. Ten trees were examined in each plot. The trees were rated from 0 to 4, the numbers signifying as follows: 0, no scale found; 1, a few scale found; 2, 2 or 3 lightly infested patches of scale; 3, patches of scale quite generally distributed, but no heavy incrustations of scale found; 4, patches of scale quite generally distributed and some portions of the foliage so heavily infested that the scale formed conspicuous incrustations.

The method employed for post-treatment estimates of population density

differences involved the counting of the number of adult female yellow scale on the 10 fruits which appeared from rapid inspection to be the most heavily infested in each of the two quadrants of the north half of the tree. Counts were made on 10 trees in each plot.

the same trees on September 21, 1945, resulted on a chlorosis of a small percentage of the leaves on some trees. The chlorosis consisted in a yellowish discoloration of the margins of the leaves, leaving the centers a dark green (fig. 2). The leaves regained their normal color

Table 6.—Results with DDT dissolved in light medium oil or kerosene and used against the yellow scale.

Treatment Number	Treatment[1]	Initial External Deposit of DDT; Mg./sq. cm.	Relative[2] Infestation Before Treatment	Number of Scales per Fruit 10/4/46	Corrected Relative Infestation (Oil Spray=100) 10/4/46
1	Oil, 1.67%	—	1.6	3.5	100
2	Oil, 1.6%; DDT, 4.7%	4.8	1.0	3.2	146
3	Oil+10% tetralin, 1.67%; DDT, 9.4%	7.1	0.7	3.4	222
4	Kerosene, 3% DDT, 4.7%	11.5	1.9	1[3] 55.6	1,338
				2 18.7	450
5	Kerosene+10% *Velsicol AR-60*, 3%; DDT, 9.4%	26.8	1.4	1 7.2	235
				2 2.3	75
6	Kerosene+10% tetralin, 3%; DDT 9.4%	26.7	1.4	1 8.6	281
				2 4.4	144
7	Kerosene+1% aluminum stearate and 10% tetralin, 3%; DDT, 9.4%	33.7	1.3	1 8.1	231
				2 0.8	28

[1] Blood albumin spreader at 4 ounces to 100 gallons of spray was used in all treatments. The concentration of DDT is expressed in weight per cent. The first application of spray was made on July 18, 1945. The second applications, in the portions of the plots sprayed twice, were made on September 21, 1945.

[2] Both pre-treatment and post-treatment estimates of relative population densities were made differently than those which were made for red scale, because of the difference in the type of distribution of the two species in the tree. See text for an explanation of the methods employed for the yellow scale.

[3] The figures in this column show the number of treatments. In the plots sprayed with kerosene, half of each plot was resprayed on September 21, 1945.

The data presented in table 6 indicate that DDT, when added to spray oil, may actually reduce the effectiveness of the treatment. Light medium oil spray became progressively less effective as larger quantities of DDT were added to the spray. In all plots sprayed with 3 per cent kerosene with 9.4 per cent DDT ,the population of yellow scale was over twice as high as in the plot in which 1.67 per cent light medium oil was used. In marked contrast are the results with this solution in red scale control, in which, in all but one treatment, the 3 per cent dosage of kerosene with 9.4 per cent DDT resulted in better long-term control of red scale than the light medium sprays.

EFFECT OF DDT ON CITRUS TREES.—Although experiments were made in 14 citrus orchards in 7 counties, there were only 2 orchards in which certain symptoms indicating a mild phytocidal effect were noted. In a Navel orange orchard near Exeter, Tulare County, sprays of 3 per cent kerosene containing 9.4 per cent DDT, applied July 18, 1945 and again on within a month or two without dropping.

In a lemon orchard in Rialto, San Bernardino County, a yellowish discoloration was noted along the midribs and veins of a small percentage of the leaves in a plot sprayed with 5 per cent

FIG. 2.—A chlorosis of the outer margins of Navel orange leaves sprayed with 3 per cent of a kerosene solution containing 10 per cent tetralin and 9.4 per cent DDT.

kerosene containing 4.7 per cent DDT (table 4, experiment 2, treatment 4). In an adjoining plot treated with the same spray except that 1 per cent aluminum stearate was added to the kerosene, none of the leaf symptoms were found. This was probably due to the effect of the aluminum stearate in preventing penetration of the kerosene. Also in plots sprayed with 3 per cent DDT-kerosene, no leaf symptoms were found.

In the lemon orchard, some of the mature leaves fell to the ground before normal color was restored; other leaves gradually regained their normal color. In neither the orange orchard nor the lemon orchard was defoliation appreciably increased on trees in which the leaf symptoms were observed.

Aside from the leaf sypmtoms mentioned above, no discernible adverse affects of DDT were observed. This relative lack of phytocidal effect further substantiates observations based on extensive field experimentation during the 1943-44 season (Ebeling, 1945). In 1944, 14 orange and 10 lemon trees were repeatedly sprayed with 3 per cent kerosene containing 4.7 weight per cent of DDT. The trees were sprayed 7 times, during an 8.5 months period, without ill effects (Ebeling 1945). In 1945–46 the same trees were sprayed 6 times during the period from July 5, 1945 to January 15, 1946, again without visible injurious effects attributable to DDT. By this time, however, injury to the bark, beneath the soil line, also found on check trees sprayed with the same dosage of kerosene without the DDT, was discovered. This was similar to the sub-soil injury sometimes caused by 10 per cent kerosene when it is allowed to accumulate in depressions which are occasionally found around the trunks of citrus trees. Such injury, however, has not been found where sprays, of the usual commercial gallonage per tree, of 3 per cent DDT-kerosene, either in the single treatment or in the double treatment, have been used.

EFFECTS OF DDT-KEROSENE SPRAY ON FRUIT QUALITY AND WATER SPOT.—Repeated chemical analyses have revealed no evidence that 3 per cent DDT-kerosene affects the concentration of sugar, acid, and soluble solids of oranges, when comparisons are made with fumigated or untreated fruit.[11] This is of special interest in view of the fact that light medium spray oil, as used in the control of citrus pests in southern California, has usually adversely affected the quality of oranges (Sinclair, Bartholomew, and Ebeling, 1941).

Another adverse effect of spray oil which may be avoided when kerosene is used as a carrier for DDT, is the tendency of the oil to accentuate the malady of Navel oranges known as water spot, which has been discussed previously in this paper. Many experiments, made over a period of years, have shown no increase in the incidence of water spot in kerosene-treated plots when these were compared with untreated plots.

Experiments with Di-2-Ethyl Hexyl Phthalate.—Field experiments were made with di-2-ethyl hexyl phthalate, a viscous liquid which is a good solvent for DDT. A concentration of 30 per cent by weight of DDT was incorporated in the liquid, and the resulting mixture was applied to Navel orange trees on November 21, 1945, at 0.25 and 0.5 per cent. A fair degree of red scale control was obtained with the 0.5 per cent dosage (see table 4, experiment 3, treatment 6), and since no ill effects to the tree or fruit were noted, it is possible that still higher dosages could be safely used. Fruit was picked from 25 to 37 days after treatment and placed in an "artificial rain chamber" for periods of from 1 to 3 days, being kept continuously wet during this period under conditions simulating rain. In a series of experiments, using 50 fruits per lot and with 4 replications, no more water spot was found on fruit sprayed with di-2-ethyl hexyl phthalate than on untreated or kerosene-sprayed fruit.[12]

SUMMARY.—DDT was dissolved in light medium spray oil and in kerosene at concentrations resulting in 4.7 weight per cent and 9.4 weight per cent of DDT. Four ounces of blood albumin spreader per 100 gallons of spray was used in nearly all the sprays. The DDT solutions were prepared by dissolving the DDT in the petroleum after the latter had been heated to 60° C. When a 9.4 per cent solution of DDT was prepared, 1 part by

[11] Data on file at the Division of Plant Physiology, University of California Citrus Experiment Station, Riverside, California.

[12] Data on file at the University of California, Los Angeles. The di-2-ethyl hexyl phthalate was supplied to the University for the purposes of this investigation, under the designation of 899, by the American Cyanamid Company.

volume of mutual solvent was added to 9 parts of petroleum before the DDT was added. The mutual solvents generally used were *Velsicol AR-60* and tetralin. When the DDT was to be dissolved in the orchard and used immediately, only 5 per cent by volume of the mutual solvent was used. The DDT was briefly stirred in the mutual solvent-petroleum solution and the mixture was then forced through the spray pumps for 1 or 2 minutes, thus dissolving the DDT. The reduced amount of mutual solvent proved to be satisfactory when the solution was used immediately and was not subjected to low night temperatures.

A few plots were sprayed with 40 per cent wettable DDT, using 5 pounds of this powder, a pound of *DDT depositor* and a quart of kerosene to 100 gallons of spray.

In determining the relative infestation of adult female red scale in plots sprayed with different concentrations of DDT in light medium oil, corrections were made for original differences in scale population in the plots. The infestation in the oil-sprayed plot was arbitrarily considered to be 100. On the basis of population estimates made from 4 to 14 months after treatment, and averaging the results of 5 experiments, the infestation in plots sprayed with oil plus 4.7 per cent DDT was found to be 65.3, and in the plots sprayed with oil plus 9.4 per cent DDT, 40.3. Thus there were on an average about 2.5 times as many scales remaining in the plots sprayed with 1.75 per cent light medium oil as in the plots sprayed with the same amount of oil to which had been added 9.4 weight per cent DDT. In another experiment, however, oil with 9.4 per cent DDT was found to be inferior to oil alone.

When 3 per cent kerosene containing 4.7 per cent DDT was used, in all but 1 plot the results were inferior to that of oil spray. On the other hand, the 3 per cent dosage of kerosene with 9.4 per cent of DDT resulted, in all but 1 experiment, in a lower population of red scale than that which was found in the oil-sprayed plots.

When 2 treatments of 3 per cent DDT-kerosene were applied, the second following the first by about 2 months, the control of red scale was always far superior to that obtained from 1.67 or 1.75 per cent of light medium spray oil. It was found that if the first of the 2 treatments is applied in the conventional manner, with a thorough wetting of the tree, the second treatment may then be applied with a reduced gallonage per tree and directed only against the outside surface of the tree, where decomposition of DDT takes place most rapidly.

Aluminum stearate, when dissolved in kerosene, prevents or retards the penetration of kerosene into foliage and bark of citrus trees. At 1 per cent concentration in DDT-kerosene, the aluminum stearate increased the insecticidal effectiveness of the sprays.

An experiment made with yellow scale indicated that DDT is not as effective when used against this insect as it is in the control of the red scale.

A yellowish discoloration of a small percentage of the leaves of some trees was noticed in 2 out of the 14 orchards in which experiments were made. The symptoms were somewhat different on orange and lemon. The leaves gradually regained their normal color and there was no greater leaf drop from affected trees than from trees on which the chlorosis was not found.

Repeated chemical analyses have never revealed any adverse effect of 3 per cent DDT-kerosene on fruit quality as indicated by concentration of sugar, acid and soluble solids.

Three per cent DDT-kerosene does not increase the incidence of water spot, a malady affecting Navel oranges after prolonged periods of rainy or wet weather. The incidence of this malady is usually greatly increased, however, by regular oil sprays.

Di-2-ethyl hexyl phthalate, with 30 per cent by weight of DDT, was used at 0.25 and 0.5 per cent, adding 4 ounces of blood albumin spreader to 100 gallons of spray. Based on population estimates made 13 months after application, this treatment was inferior to 1.75 per cent light medium oil spray. This handicap might be overcome if the dosage could be increased with safety to the tree, or if repeated applications were used. Of special interest in connection with the use of di-2-ethyl hexyl phthalate is its relation to the Navel water spot problem. Navel oranges picked 25 to 37 days after treatment were kept continuously wet for 1 to 3 days in "rain chambers" in which a

condition simulating rain was artificially produced. No more water spot was found in fruit from trees sprayed with di-2-ethyl hexyl phthalate than in fruit from untreated trees or from trees sprayed with 3 per cent DDT-kerosene.

LITERATURE CITED

Baier, W. E. 1946. A method for the quantitative estimation of DDT in plant and/or sulfur-containing materials. Science **104**(2703): 376–7.

Ebeling, W. 1945a. DDT and rotenone used in oil to control the California red scale. JOUR. ECON. ENT. **38**(5): 556–63.

Ebeling, W. 1945b. DDT penetration prevented by adding aluminum stearate to DDT-kerosene solutions. JOUR. ECON. ENT. **38**(6): 689–91.

Gunther, F. A. 1945. Quantitative estimation of DDT and of DDT spray or dust deposits. Ind. Eng. Chem. **17**: 149–50.

Gunther, F. A., M. I. Elliot, J. P. LaDue, and D. L. Lindgren. 1947. Persistence of certain DDT deposits under field conditions. JOUR. ECON. ENT. **39**: 624–7.

Lindgren, D. L., J. P. LaDue, and Doris Dow. 1944. Preliminary studies with DDT in the control of the California red scale. Calif. Citrog. **29**(7): 180–1.

Sinclair, W. B., E. T. Bartholomew, and W. Ebeling. 1941. Comparative effects of oil spray and hydrocyanic acid fumigation on the composition of orange fruits. JOUR. ECON. ENT. **34**(6): 821–9.

Control of Japanese Beetles at Second Army Posts

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The Japanese beetle, *Popillia japonica*, is a serious pest in much of the Second Army area which includes Ohio, Indiana, West Virginia, Virginia, Kentucky, Pennsylvania and Maryland. Larval damage is frequently found on grassed areas such as parade grounds, golf courses and lawns. This damage has necessitated costly reseeding to maintain dust and erosion control at many posts. The adults constitute a serious hazard to certain favored ornamentals, and adversely affect the morale of personnel when the beetles are flying in large numbers. The adults tend to concentrate and feed to a damaging extent on certain ornamentals even on posts where the larval populations are so low that no grass damage is encountered. Consequently two distinct problems are faced in the control of the insect, the rather fixed larval population in the well maintained grassed areas and the mobile adult population which concentrates on the post from lightly infested areas on or off post. Both problems are considered separately, although solution of the first assists materially in solving of the second.

The discovery and development of milky disease, *Bacillus popilliae*, by the Moorestown Laboratory, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, has provided an effective and inexpensive method for preventing larval damage to turf. This laboratory has cooperated fully with army posts in making surveys to determine whether sufficient larvae were present to justify the use of the milky disease spore dust, furnishing the necessary amount of the insecticide and providing supervisory personnel to insure its proper distribution. Since 1940 milky disease spore dust has been applied to 18 army posts as shown in table 1. The results have been very satisfactory with no turf damage by larvae found after the disease was well established. This has usually required about 2 years. Only the well maintained grassed areas are treated, figure 1, as these areas attract the female adults in great numbers for egg laying. Light egg deposition occurs on poor grass stands or weeds elsewhere on the post which provides a continual scattered population of larvae, but in numbers too low to cause any turf damage. The low population of adults produced in such spots provides an ample population to cause defoliation damage when concentrated on a few susceptible trees.

Ornamental shrubs and trees susceptible to attack by adult Japanese beetles are commonly found in the plantings at permanent army posts. As indicated above, beetles from lightly infested areas concentrate on these favored trees and

Table 1.—Army posts treated with "milky disease" in Pennsylvania, Maryland and Virginia.

LOCATION	INSTALLATION	DATE OF TREATMENT	APPROX. NO. ACRES	SPACING	POUNDS OF SPORE DUST
Pennsylvania	Middletown Air Depot	5/1/41	158	10′×20′	138.25
	New Cumberland General Depot	4/29–30/41	132	10′×20′	115.50
	Marietta Transportation Corps	11/15/45	11	10′×10′	19.25
	Carlisle Barracks	3/13/46	110	10′×10′	183.75
Maryland	Aberdeen Proving Ground	4/7–9/41	368	10′×20′	322.00
		3/1–2/44	75	10′×10′	130.00
	Edgewood Arsenal	4/9–10/41	264	10′×20′	231.00
		3/3–4/44	100	10′×10′	157.50
	Ft. Geo. G. Meade	4/10–17/41	300	10′×20′	236.25
	Ft. Holabird	4/4/41	58	10′×20′	50.75
	Ft. Washington	10/21/43	60	10′×20′	47.25
	Andrews Field	4/2/46	30	10′×10′	52.50
	*Curtis Bay Ord. Depot	1942	3	10′×10′	6.00
Dist. of Columbia	Army War College (Ft. Humphries)	10/22/40	74	10′×20′	64.75
	Army Medical Center	10/23/40	68	10′×20′	59.50
		9/17/46	6	10′×10′	10.50
	Bolling Field	10/24/40	418	10′×20′	365.75
	Ft. McMillan	8/20/42	5	10′×20′	6.00
Virginia	Arlington Hall	4/10/44	20	5′× 5′	47.25
	Ft. Belvoir	4/3–4/45	194	10′×10′	349.50
	Ft. Hunt	4/5/45	30	10′×10′	52.50
Totals:			2484		2645.75

shrubs. Traps for catching adults tend to attract beetles which also concentrate on favored plants. For this reason adult traps are not recommended for use at army installations. Favored trees and shrubs require a protective spray cover for years after milky disease has become established and has stopped larval damage to turf.

In 1944 some protection to foliage was afforded by the use of a repellent lime spray, but this was not entirely satisfactory. Common arsenical or other insecticides were very scarce and needed for crop protection. Fortunately the population of adults was low since very little protective spraying could have been done. Little damage resulted.

In 1945 there were more adult beetles and a greater need for protective spraying. DDT seemed to offer good possibilities for foliage protection. A small supply of 50 per cent wettable DDT was obtained from the experimental use. This was tried against Japanese beetle adults on two army posts. Phenomenal results were obtained at one post, but at the other post results, while promising, were difficult to evaluate because of the incessant rainfall after the spray application. A dosage of 2 pounds total material per hundred gallons of water was recommended. It is believed that this rate was increased considerably at the first post. Other limited tests on rose bushes, elms and altheas gave complete foliage protection with two cover sprays during the period of adult abundance. The feeding on flowers was reduced greatly, but not eliminated.

A heavy population of adult beetles emerged in 1946. Protective spraying was needed on all posts in the vicinity of Baltimore, Maryland, Washington, D. C. and Harrisburg, Pennsylvania. Wettable DDT was recommended, but not available at all times. Some other materials including a repellent were used but none gave results even closely approaching the wettable DDT in effectiveness. A dosage of two pounds of 50 per cent wettable DDT per hundred gallons of water was generally used. The residual effect was noted for more than thirty days.

In the course of aerial spraying for mosquito control with a cargo plane the effect of 20 per cent DDT-oil spray was noted on adult beetles feeding heavily on a large linden. The ground below the tree was completely covered with dying beetles 3 hours after spraying. Three hours later, (6 hours after the spraying), the

FIG. 1.—Application of "Milky Disease" spore dust to grassed portion of an Army Post. Distribution is made with 10′×10′ spacing.

outer leaves of the tree were almost covered again with feeding beetles, indicating that there was no residual effect. The aerial spraying was done at a rate of 0.20 pounds of DDT per acre flown in approximately 100 yard swaths. It was evident that the linden tree was directly under the plane and received the maximum dosage, because observations at other points where the beetles were abundant did not indicate comparable mortalities. All the terrain within a half-mile of the linden tree was covered by the aerial spray leaving many adults uninjured as evidenced by the abundance of feeding beetles six hours after the spraying.

One unusual request for control of Japanese beetle adults involved saving a 2-acre field of sweet corn. The beetles were feeding heavily on the ears with the heaviest damage occurring through loss of about 1.5 inches of the kernels on the tip of the ears. Up to 30 beetles were found on a single ear. A decontamination unit M3A2 (orchard sprayer) was available, equipped with an orchard gun and Bordeaux nozzle. A spray was prepared at the rate of two pounds of 50 per cent wettable DDT per hundred gallons of water. One trip was made across the cornfield in mid-afternoon on July 31, 1946, utilizing the full drift of a slight breeze on one side and spraying into the breeze on the other side at a pressure of 400 pounds per square inch. By lifting the gun to a 45 degree angle an effective, visible deposit was put down on the foliage for over 100 feet with the wind and for 50 feet into the wind. About 125 gallons of spray was used on the 2 acres. An hour after the spraying,

Table 2.—Counts of Japanese beetle adults feeding on sweet corn ear tips following spraying with 50 per cent wettable DDT, 31 July 1936.

Lot Number	Ears	Number of Japanese Beetles	
		Sprayed Area	Check Area
1	10	7	77
2	10	0	35
3	10	11	44
4	10	12	34
5	10	4	9
6	10	4	83
7	10	2	91
8	10	9	85
9	10	11	128
10	10	6	75
Totals:	100	66	673

counts were made of the number of beetles feeding on the ear tips at various places in the sprayed area. A similar number were counted in a supposedly check area, but unfortunately this area had been affected by the spray. All high ears or ears facing the direction of the spray were free of beetles even though showing signs of heavy feeding. Check counts should have been taken before the spraying when the total would have been much higher. Ten ears were counted in each lot taking one at random, counting the beetles on it and the 9 adjacent ears. The comparative totals are shown in table 2.

On the following day, the field was examined and practically no beetles were found feeding anywhere in the field, including the area beyond where a visible deposit was noted on the foliage. Dead and dying beetles were found easily in the axils of the leaves and all over the ground. The corn was ready to be harvested within a week so no further counts were made.

SUMMARY.—Milky disease spore dust has proven to be an effective and inexpensive method of preventing Japanese beetle larval damage to turf. Wettable DDT used as a foliage spray has given excellent protection to susceptible trees against attacks of Japanese beetle adults. Wettable DDT was used as a foliage spray to save a small field of sweet corn from serious damage by the adult beetles.—4-23-47.

Comparative Residual Effectiveness of Organic Insecticides Against House Flies and Malaria Mosquitoes[1]

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Practical control of adult house flies and mosquitoes by DDT insecticidal films has been amply verified. Further advances on different types of organic compounds has led to the development of several new materials with residual toxic properties. Although these new insecticides must be considered eventually over a range of formulations against a variety of insects in many special control problems, it has been necessary to start with a comparison of the effectiveness of each insecticide in certain basic formulations.

The insecticides herein considered are (1) benzene hexachloride (1, 2, 3, 4, 5, 6-hexachlorocyclohexane); (2) DDD (2, 2-bis(parachlorophenyl)-1, 1-dichloroethane), (3) chlordane ($C_{10}H_6Cl_8$), (4) *Toxaphene*[2] (a chlorinated camphene containing 68 per cent chlorine), (5) di-2 (ethyl hexyl) phthalate, and (6)–(7) combinations of pyrethrins with piperonyl butoxide and piperonyl cyclohexenone. Tests on water-wettable DDT powders and specified DDT by-products have been included as these represent more recent developments in DDT technology.

Procedure.—As a basis of comparison, 2.5-or 5-per cent concentrations of the test insecticides were prepared as emulsions, solutions, or suspensions if solubility permitted. Xylene or kerosene was used as the solvent with *Triton X-100*[3] as the emulsifier. The test sprays were applied at the rate of 4 cc. per square foot to give residual deposits of 100 or 200 mg. of the insecticide per square foot. Plain plywood was utilized as the test surface.

The testing technique involved has been previously described for mosquitoes (Fay *et al.* 1947) and for house flies (Fay *et al.*[4]). In brief, a sample of either species was transferred from the stock cage to an exposure chamber composed of a rectangular wooden framework into which four 3- by 12-inch test panels were inserted to form the sides. These panels had been previously sprayed as a single flat surface of one square foot. The ends of the chamber framework had circular openings to permit the introduction and removal of test insects. After the exposure period, the insects were blown into a wire holding cage and provided with food and water. The same procedure was followed with control samples, except untreated panels were used in the exposure chamber. Any mortality in the controls was taken into account in the evaluation of the results.

In tests with mosquitoes, a sample containing approximately twenty-five 4-day-old, insectary-reared, adult *Anopheles quadrimaculatus* females and a variable number of similar males were exposed for test periods of 30 or 60 minutes. The immediate knockdown of the females, and the twenty-four-hour mortalities of each sex were recorded.

In tests with house flies, a sample of approximately sixty-six well-fed, 3-day-old, adult *Musca domestica* of both sexes was exposed for test periods of 15 or 30 minutes. The immediate knockdown and twenty-four-hour mortalities of each sex were recorded in this case.

There being some variation among successive batches of insectary-reared flies, it was considered desirable to make some adjustment for the mortality in untreated checks from each batch. The method selected was to calculate the percentage of kill by the formula $(D-E)/(T-E)\times 100$ in which T was the total number of insects in the test; E, the number of dead expected in a control run of size T; and D, the number of dead mosquitoes in the sample.

In presenting the chronological data graphically, a smoothing formula (based on the assumption that short portions of the curve approach a straight line) was used as follows: $B'=(A+2B+C)/4$, in which B′ was the corrected point as plotted; A, the reading of the previous period; B, the reading to be corrected; and C, the reading of the following period.

[1] From Communicable Disease Center, Technical Development Division (Savannah, Ga.)

[2] *Toxaphene* is a product of the Hercules Powder Co., Wilmington, Delaware.

[3] *Triton X-100* is a product of the Rohm and Haas Co., Philadelphia, Pa.

[4] Unpublished Report.

Appropriate adjustments in the formula were made for the first and last points. The symbols A, B, and C represent the average of two or more runs in every case.

RESULTS.—*Benzene Hexachloride*: The two products tested contained 10 and 30 per cent gamma isomer respectively. Both dissolved only partially in kerosene or xylene and left an insoluble sludge in the test solutions. The 30-per cent-gamma benzene hexachloride containing 30 per cent gamma isomer. In this case it was difficult to secure a uniform coverage as sludge caused clogging of the spray nozzle. With this exception the effectiveness of the benzene hexachloride is correlated positively with the concentration of the gamma isomer. Since it has been technically difficult to obtain benzene hexachloride with more than 30-per cent-

Table 1.—Twenty-four-hour mortalities (per cent) of *Anopheles quadrimaculatus* adult females from 60-minute exposures to deposits of various insecticides at indicated times after spray application.

Insecticide	Solvent	Mg. per Sq. Ft.	Age of Residue (Weeks) 1	4	8	16	20	24	28	32	36
5% Benzene hexachloride (30% g)	Xylene	200[1] (60)	100	100	100	61	—	14	—	2	6
2% Benzene hexachloride (30% g)	Kerosene	100[1] (30)	100	97	93	100	—	82	—	55	31
2.5% Benzene hexachloride (30% g)	Xylene	100[1] (30)	100	100	90	100	—	86	—	15	9
5% Benzene hexachloride (10% g)	Xylene	200[1] (20)	100	100	97	96	—	10	—	34	—
1.25% Benzene hexachloride (10% g)	Kerosene	100[1] (10)	100	100	85	100	—	35	—	21	18
2.5% Benzene hexachloride (10% g)	Xylene	100[1] (10)	100	97	88	79	—	0	—	0	—
5% DDD	Kerosene	200	97	86	96	72	—	—	—	48	47
5% DDD	Xylene	200	89	—	71	60	—	—	—	42	42
5% DDD	Kerosene	100	91	100	52	23	—	—	—	41	34
5% DDD	Xylene	100	19	100	57	49	—	—	—	49	46
5% Chlordane	Kerosene	200	—	—	100	71	45	50	39	24	—
5% Chlordane	Xylene	200	—	—	100	63	40	31	50	16	—
2.5% Chlordane	Xylene	100	—	—	46	14	9	3	—	—	—
5% Water-wettable *Toxaphene*	Water	200	—	—	97	85	72	12	55	19	13
5% Tech. *Toxaphene*	Xylene	200	—	—	92	13	25	—	—	—	—
0.25% pyrethrins+5% piperonyl cyclohexenone	Kerosene	10[2] (200)	—	50	—	37	—	41	47	40	32
0.025% pyrethrins+0.5% piperonyl cyclohexenone	Kerosene	1[2] (20)	—	35	—	13	—	—	—	—	—
5% DDT	Xylene	200	—	93	89	91	—	81	69	56	71
5% DDT	Kerosene	200	—	84	78	77	—	69	47	42	67

[1] Top number indicates total benzene hexachloride, number in parentheses the gamma isomer.
[2] Top number indicates pyrethrins, number in parentheses the piperonyl cyclohexenone

product was more soluble than the 10-per cent material. The finished sprays tested were xylene emulsions containing 2.5 and 5 per cent of the technical product (both 10- and 30-per cent-gamma-isomer types) a kerosene emulsion containing 2 per cent total (30-per cent-gamma-isomer type), and a kerosene solution containing 1.25 per cent total (10-per cent-gamma-isomer type) benzene hexachloride.

The laboratory tests with benzene hexachloride against *Anopheles quadrimaculatus* adult females demonstrated generally an adequate effectiveness over a 16-week period, the only exception being the tests on the deposits of 200 mg. total gamma-isomer content, the solubility of the technical product represents a limiting factor in securing higher gamma-isomer deposits. In addition, the present products have a persistent, penetrating odor which makes their use in dwellings undesirable.

DDD: The insecticide DDD was tested in two combinations: (a) a 5 per cent solution in kerosene, and (b) a 5-per cent-DDD xylene emulsion. A xylene-*Triton X-100* concentrate containing 35 per cent DDD was diluted 1:6 with water to form the 5 per cent finished emulsion spray.

The applications of 200 mg. DDD per square foot against *Anopheles quadri-*

maculatus females (Table 1) were satisfactory at 8 weeks, but the applications of 100 mg. DDD per square foot were not satisfactory within this period. In similar tests against the house fly (Table 2) the DDD was not satisfactory and demonstrated little initial toxicity.

Chlordane: The insecticide, chlordane ($C_{10}H_6Cl_8$), was tested in three combinations: (a) a 5-per cent-chlordane kerosene emulsion prepared by cutting a 25-per cent-chlordane, 5-per cent-*Triton X-100*, kerosene concentrate 1:4 with water; (b) a 5-per cent-chlordane xylene emulsion prepared by cutting a 35-per cent-chlordane, 4-per cent-*Triton X-100*, xylene concentrate 1:6 with water; and (c) a 2.5 per cent-chlordane xylene emulsion prepared by cutting the 35 per cent concentrate 1:13 with water.

The application of 200 mg. chlordane per square foot was not satisfactory against adult female *A. quadrimaculatus* (Table 1) at the end of a 16-week period. The 100-mg. dosage was not satisfactory at the end of an 8-week period.

The application of 200 mg. chlordane per square foot against adult house flies (Table 2) was satisfactory for at least 8 weeks, while the application of 100 mg. was not satisfactory even at the end of 1 week.

TOXAPHENE.—The insecticide, *Toxaphene*, was tested in two combinations: (a) a 5-per cent-*Toxaphene* xylene emulsion made by cutting 1:6 with water a xylene concentrate containing 35 per cent technical *Toxaphene* and 10 per cent *Triton X-100*, and (b) a 5-per cent-*Toxaphene* suspension prepared by suspending a 25-per cent water-wettable *Toxaphene* powder in water. Both combinations were tested at applications of 200 mg. *Toxaphene* per square foot.

In laboratory tests against adult, female *Anopheles quadrimaculatus* (Table 1) the water-wettable *Toxaphene* was more effective than the *Toxaphene*-xylene emulsion and gave satisfactory control for a 20-week period.

In tests against adult house flies (Table 2) the water-wettable *Toxaphene* was somewhat superior to the *Toxaphene*-xylene emulsion, but neither combination was entirely satisfactory.

Di-2(ethyl hexyl) phthalate: This liquid insecticide was tested as a 5-per cent water emulsion containing 4 per cent *Triton X-100* as an emulsifier. It had no residual toxicity against either *Anopheles quadrimaculatus* or *Musca domestica*.

PYRETHRINS WITH PIPERONYL BUTOXIDE.—The combination of pyrethrins and piperonyl butoxide was tested in two forms: (a) a concentrate containing 0.5-per cent pyrethrins and 4-per cent piperonyl butoxide in odorless kerosene (*Deobase*) cut 1:9 with kerosene, and (b) the same concentrate cut 1:19 with kerosene. Both combinations were applied at the rate of 4 cc. per square foot to give deposits of (a) 2 mg. pyrethrins and 16 mg. piperonyl butoxide per square foot, and (b) 1 mg. pyrethrins and 8 mg. piperonyl butoxide per square foot and tested against *Musca domestica*. Neither combination showed residual toxicity.

PYRETHRINS WITH PIPERONYL CYCLOHEXENONE.—The combination of pyrethrins and cyclohexenone was tested in two forms: (a) 0.25 per cent pyrethrins and 5 per cent cyclohexenone in *Deobase* and (b) this concentrate cut 1:9 with kerosene. Both combinations were ap-

Table 2.—Twenty-four-hour mortalities (per cent) of *Musca domestica* females from 60-minute exposures to deposits of various insecticides at indicated times after spray application.

INSECTICIDE	SOLVENT	MG. PER SQ. FT.	AGE OF RESIDUE (WEEKS)					
			1	4	8	12	16	20
5% DDD	Xylene	200	1	22	18	1	—	—
2.5% Tech. chlordane	Xylene	100	58	56	16	6	0	—
5% Tech. chlordane	Xylene	200	99	94	82	40	1	0
5% Tech. chlordane	Kerosene	200	100	98	92	36	1	0
5% Tech. *Toxaphene*	Xylene	200	19	58	49	20	2	0
5% Water-wettable *Toxaphene*	Water	200	25	54	79	26	19	5
5% DDT	Xylene	200	97	99	100	91	83	45

plied at the rate of 4 cc. per square foot to give deposits of (a) 10 mg. pyrethrins and 200 mg. piperonyl cyclohexenone per square foot, and (b) 1 mg. pyrethrins and 20 mg. piperonyl cyclohexenone per square foot.

The concentrate used against *Anopheles quadrimaculatus* adult females (Table 1)

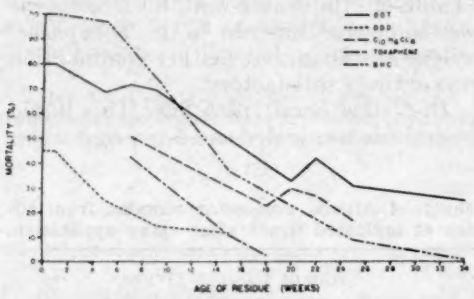

FIG. 1.—Twenty-four-hour mortality (per cent) of female *Anopheles quadrimaculatus* after 30-minute exposures at indicated times to deposits of 200 mg. of various insecticides per square foot from 5-per cent xylene emulsions applied to plywood surfaces.

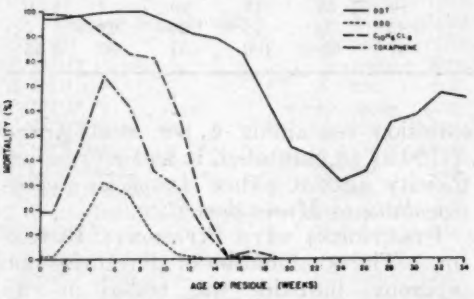

FIG. 2.—Twenty-four-hour mortality (per cent) of female *Musca domestica* after 30-minute exposure periods at indicated times to deposits of 200 mg. of various insecticides per square foot from 5-per cent xylene emulsions applied to plywood surfaces.

gave satisfactory control for at least 23 weeks, but the diluted combination was not very satisfactory even at the 4-week period.

Against adult female *Musca domestica* the concentrate showed little effectiveness.

SOLVENTS.—It is interesting to note that with equal residual applications of the benzene hexachloride gamma isomer the kerosene solutions were somewhat superior to the xylene emulsions. The kerosene solutions were also a little better than the xylene emulsion with DDD and chlordane at 200 mg. of insecticide per square foot. The kerosene solutions with DDT, however, were not as good as the DDT xylene emulsion.

SPECIES COMPARISON.—The comparative effectiveness of the various insecticides to the house fly, *Musca domestica*, and the mosquito, *Anopheles quadrimaculatus*, at equal exposure periods, is shown (Figs. 1 and 2). In general, the following points may be emphasized (a) the various insecticides remained in the same relative order of effectiveness for the two insects; (b) the loss of residual effectiveness was gradual in tests with mosquitoes and did not demonstrate the definite sharp loss seen in the tests with the house flies; and (c) the initial residual effectiveness for each insecticide showed considerable difference depending on the species of insect.

WATER-WETTABLE DDT POWDERS.—Comparisons were made on the residual effectiveness of 5-per cent-DDT suspensions made from various commercial water-wettable DDT powders. In the case of technical DDT such as is used for making xylene or kerosene emulsions and solutions, rather obvious differences in physical properties are of little practical importance in residual effectiveness of the finished sprays. However, water-wettable DDT powders obtained from different sources may appear similar, but their properties may differ so that one proves satisfactory for use in hand sprayers whereas another similar appearing product may be unsatisfactory.

Several commercial water-wettable DDT powders were tested and found to vary considerably in the DDT content, particle size, wettability, stability, flocculation, and facility of application. Biological testing demonstrated differences in residual efficiency of the different deposits against adult female *Anopheles quadrimaculatus* mosquitoes (Table 3) and also against adults of the house fly (Table 4). The different water-wettable DDT samples tested have been arranged in the order of their average effectiveness against both house flies and mosquitoes.

The variation in the residual effectiveness of the water-wettable DDT samples apparently resulted from physical differences in the samples rather than the concentration of the DDT. These differences may be compared with DDT emulsions made from concentrates containing differing solvents and emulsifiers.

Table 3.—Twenty-four-hour mortalities (per cent) of *Anopheles quadrimaculatus* adult females from 60-minute exposures to deposits of 200 mg. DDT per square foot from various water-wettable DDT powders.

Powder No.	Per Cent DDT in Powder	Age of Residue (Weeks) 4	20	24	28	32	36
1	90	91	87	90	91	76	62
2	50	84	62	58	60	48	42
3	25	81	64	71	56	34	35
4	50	95	72	68	54	34	24
5	50	92	76	54	45	32	34
6	50	39	33	28	39	32	20
7	50	76	63	43	26	18	12
8	50	67	55	49	38	17	—
Standard Emulsion	—	93	—	94	69	60	64

DDT By-Products.—Comparative tests were made on two DDT-isomer by-product mixtures (*Dycoro*[4]) of 25- and 35-per cent concentration. Chemical analysis showed approximately 11.5-per cent p, p′-DDT in the 25-per cent concentrate, and 22-per cent p′p′-DDT in the 35-per cent concentrate. Both concentrates were cut with water to form 5-per cent finished sprays and applied at the rate of 200 mg. of the toxicant per square foot.

The initial tests with these by-products gave very low mortalities in contrast to standard DDT-xylene emulsion deposits. After the initial tests, however, there was a subsequent sharp rise in toxicity and excellent residual effectiveness. Parkins & Green (1945) found that crude DDT tended to form supersaturated solutions and that the DDT was not as toxic in this form. It is quite possible that the DDT-isomer by-product concentrate acted in a similar manner and did not readily crystallize without agitation such as might be given by the test insects during the initial tests.

As shown in figure 3, after the initial low toxicity the residual effectiveness of the DDT-isomer by-products has been, in the case of mosquitoes, closely comparable to the effectiveness of technical DDT-xylene deposits and somewhat better in the case of house flies.

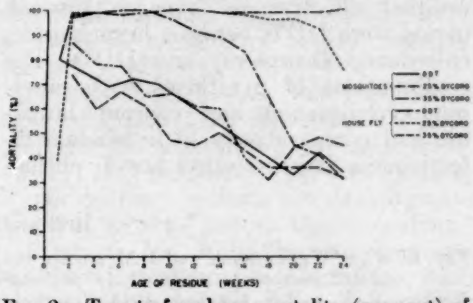

Fig. 3.—Twenty-four-hour mortality (per cent) of female mosquitoes and flies from 30-minute exposure periods to deposits of 200 mg. per sq. ft. of DDT or DDT by-products.

Table 4.—Twenty-four-hour mortalities (per cent) of *Musca domestica* adult females from 30-minute exposures to deposits of 200 mg. DDT per square foot from various water-wettable DDT powders.

Powder No.	Per Cent DDT in Powder	Age of Residue (Weeks) 1	4	8	12	16	20	24	28	32	36
1	90	100	100	100	100	99	99	99	99	98	100
2	50	100	99	96	100	100	100	100	100	100	99
3	25	100	100	100	100	100	100	100	100	100	100
4	50	100	100	98	99	100	100	100	100	100	89
5	50	100	100	100	100	100	100	99	99	98	92
6	50	99	99	99	88	71	88	96	95	72	56
7	50	100	100	98	88	96	94	73	78	52	20
8	50	100	98	98	99	98	86	77	80	36	12
Standard Emulsion	—	97	99	100	91	83	45	31	55	67	49

Summary.—Comparative evaluations of the residual effectiveness of a series of new organic insecticides against adult *Anopheles quadrimaculatus* mosquitoes and *Musca domestica* house flies have been made. Samples of test insects were exposed to deposits of the insecticide in special constructed exposure chambers for definite periods at specified times after the spray application. The twenty-four-hour mortalities were taken as the indices of residual effectiveness.

[4] *Dycoro* is a product of the Hercules Powder Co., Wilmington, Delaware.

The various insecticides were compared as xylene or kerosene sprays on the basis of 100 and 200 mg. of the insecticide per square foot with the exception of pyrethrum combinations with piperonyl butoxide and piperonyl cyclohexenone which were tested at the manufacturer's recommendations.

The various insecticides in order of their residual effectiveness over a 26-week period were DDT, benzene hexachloride, chlordane, *Toxaphene*, and DDD. The combinations of pyrethrins with piperonyl cyclohexenone and piperonyl butoxide had comparatively little residual effectiveness and di-2(ethyl hexyl) phthalate exhibited no residual effectiveness against *Musca domestica* or *Anopheles quadrimaculatus*.

The loss of residual effectiveness of most materials was gradual in tests with mosquitoes, and did not show the marked break in effectiveness evident in tests with house flies.

The individual residual effectiveness of a series of water-wettable DDT powder suspensions from different commercial sources varied considerably over a 36-week test period. Two DDT-isomer by-product concentrates had low initial effectiveness, but after the first test showed excellent residual toxicity.—7-28-47.

LITERATURE CITED

Fay, R. W., S. W. Simmons, and J. M. Clapp. 1947. Extended laboratory investigations on the toxicity of DDT residues to adults of *Anopheles quadrimaculatus*. Pub. Health Rep. **62:** (No. 5) 149–58.
Parkins, E. A., and A. A. Green. 1945. Residual films of DDT. Nature **155:** No. 3944: 688.

Benzene Hexachloride, DDT, and Chlordane for Colorado Potato Beetle Control[1]

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The successful use of DDT for the control of potato insect pests has demonstrated the value of a good over-all insecticide. Dietz (1946) pointedly has stated that "the full significance of the destructiveness of some insects has never been realized. By controlling destructive potato insects, DDT has tremendously increased potato yields."

Preliminary field trials in North Carolina by the writer in 1943 (Anon. 1944) demonstrated the success of 3 per cent DDT dust for the control of the major potato pests including the potato flea beetle, *Epitrix cucumeris* (Harr.), the tobacco flea beetle, *E. hirtipennis* Melsh., and the larvae and adults of the Colorado potato beetle, *Leptinotarsa decemlineata* (Say). Subsequent field trials conducted in heavily infested flea beetle fields of the Blue Ridge Mountain area have corroborated these early trials. DDT 3 to 5 per cent dust is now used extensively for flea beetle control in this area.

The advent of newer formulations of DDT has stimulated further interest in its use. Water miscible forms for agricultural crop pest control show promise of increased efficiency of control. The increase in efficiency is indicated not only in better control of insects but also in the reduced amount of insecticide necessary per application. Bronson & Smith (1946) have reported successful control of potato aphids with only one-half pound of DDT per acre. Glasgow (1946) has indicated that DDT applied as an emulsion appears to be more effective than a suspension of DDT.

Some of the newer DDT formulations, as well as other organic insecticides, were tested for the control of the adults and the larvae of the Colorado potato beetle. This paper is a report on the results of these tests.

MATERIALS USED.—Various DDT formulations, including dust and water miscible forms, as well as other organic insecticides were used in small field tests conducted at Raleigh in 1946. Table 1 lists

[1] Contribution from the Department of Zoology and Entomology of the North Carolina Agricultural Experiment Station. Published with the approval of the Director as Paper No. 259 in the Journal Series.

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Table 1.—Materials used for Colorado potato beetle larval control and percentage mortalities obtained one day after treatment.

MATERIAL	No. PINTS IN 100 GALS.	PERCENTAGE ACTIVE INGREDIENT IN FINISHED SPRAY	PERCENTAGE KILL ONE DAY AFTER TREATMENT
DDT emulsions			
Powell JP25[1]	1	.03125	81.9
Powell JP25	2	.0625	90.0
Powell 525	1	.03125	65.7
Powell 525	2	.0625	71.2
Penco 531-S[2]	1	.04075	61.2
Penco 531-S	2	.08150	92.6
Penco 531-S and polyethylene pentasulphide[3]	2	.08150	79.4
Dapspray[4]	2	.075	87.0
Neocid M25[5]	2	.0625	87.7
Gesarol E25[5]	2	.0625	83.6
Cytox no. 10[6]	2	.0625	87.4
DDT in xylol	2	.0625	85.4
DDT-*1068*	2	.03125 of each	92.1
DDT dusts			
Cytox 3%			86.3
Cytox 1%			61.4
DDT wettable powder			
Cytox 50%	2 lbs.	.12	83.0
Benzene hexachloride			
30% emulsion concentrate (9% gamma isomer)[2]		.0125	95.9
5% dust (1% gamma isomer)[7]			84.5
50% wettable powder (6% gamma isomer)[7]	2 lbs.	.014	83.5
Other materials			
Chlordane[8] (technical grade)	2	.24	91.7
Pyrenone no. 20[9]	12	1.4	50.3

[1] Powell formulas supplied by John Powell and Co., New York.
[2] Supplied by Pennsylvania Salt Manufacturing Co., Philadelphia.
[3] Polyethylene pentasulphide supplied by B. F. Goodrich Chem. Co., Cleveland.
[4] Supplied by Doggett-Pheil Co., Springfield, New Jersey.
[5] Supplied by Geigy Co., New York.
[6] *Cytox* materials supplied by American Cyanamid and Chem. Corp., New York.
[7] Supplied by California Spray-Chemical Corp., Elizabeth, New Jersey.
[8] Supplied by the Velsicol Corp., Chicago.
[9] Supplied by Dodge and Olcott Co., New York.

the materials used and the concentrations at which they were applied.

Four DDT emulsions contained 25 per cent by weight technical grade DDT (mostly the para-para isomer). *Powell 525*, also a 25 per cent DDT concentrate, had a high content of the ortho-para isomer. *Penco 531-S* concentrate contained 32.6 per cent by weight of technical grade DDT. All of these brands were supplied by the manufacturers. The DDT-xylol emulsion, 25 per cent by weight of technical grade DDT, was prepared by the author. Only one of the emulsions was used with a spray adjuvant added to it. This was the water miscible DDT labeled *Penco 531-S* which was used at the rate of one quart of the concentrate to 100 gallons of water with one quart of the spray adjuvant, polyethylene pentasulphide, added to it. The DDT-chlordane emulsion contained 25 per cent by weight of technical grade DDT and 25 per cent by weight of chlordane. *Dapspray* contained 30 per cent by weight of technical grade DDT plus an unstated amount of rotenone.

Chlordane was also used alone as a spray. This new insecticide is described as a chlorinated hydrocarbon with the empirical formula $C_{10}H_6Cl_8$ and it is probably a mixture of several isomers (Kearns *et al.*).

Benzene hexachloride was used as a 5 per cent dust (1 per cent gamma isomer content), and as a dilute spray made from a 30 per cent emulsion (9 per cent gamma isomer content) or from a wettable powder of 6 per cent gamma isomer content.

Pyrenone No. 20, a piperonyl cyclohexanone-pyrethrum concentrate was used as a spray. This material contained six grams of piperonyl cyclohexenone and 600 milligrams of pyrethrins per 100 cc. of stock solution and was used at the rate of 12 pints of stock solution to 100 gallons of water.

Emulsifiers were used with three of the formulations. *Triton X-155M*[1] was used as the emulsifier for the DDT-xylol concentrate and *IN-3622*[2] was used with chlordane concentrate, DDT-chlordane emulsion, and with *Pyrenone No. 20*.

PROCEDURE.—All sprays were applied with a knapsack type sprayer capable of delivering the spray at a pressure of 200 pounds. Spray applications were made at the rate of 100 gallons per acre. Dusts were applied with a rotary hand type duster at about 25 to 30 pounds per acre. Treatments were replicated four times on plots consisting of one row of 10 lineal feet. Potatoes were about 12 inches high at the time of the first application on June 8 and somewhat taller at the time of the second application on July 8 although by this time the plants had begun to fall over.

Applications were made in the morning or toward mid-day when the dew had dried. A total of 16 different treatments was used in the first application of June 8. In the second application of July 8, five new treatments were used in addition to the original 16, making a total of 21 different treatments for this date.

All plots were examined before each treatment and a count was made of the

[1] Supplied by Rohm and Haas, Philadelphia, Pa.
[2] Supplied by E. I. du Pont de Nemours, Wilmington, Dela.

Colorado potato beetle adults and larvae in each plot. The plots were again examined one day after treatment to check on the number of insects killed as well as to observe any phytotoxicity. The percentages of reduction in the number of larvae observed in these two examinations are listed in table 1. Mortalities obtained in the first application on June 8 were generally duplicated in the July 8 test. For this reason, the data for only the second test are presented in table 1.

RESULTS.—The speed of the knockdown obtained with most of the formulations was rather marked within 24 hours after treatment. Not all of the formulations, however, had the same degree of toxicity to the larvae within this 24-hour period. With certain exceptions, most of the formulations had enough residual power to be effective in killing larvae three days after treatment. At the end of three days, nearly all of the formulations were about equal in toxicity.

The mortalities observed one day after treatment were used as a basis for evaluating the effectiveness of the various formulations. In general, the DDT preparations gave a high degree of control and were more efficient at the 2 pints per 100-gallon concentration than at the 1 pint per 100-gallon concentration. Upon statistical analysis it was found that the DDT preparations at the 2 pints per 100-gallon concentration did not vary significantly between themselves but it should be noted that *Powell 525* (high in ortho-para DDT) was quite low relative to the average. *Penco 531-Sm* with spray adjuvant added, was also low compared to the average.

The mortalities obtained with the DDT formulations, *Powell JP25*, *Powell 525*, and *Penco 531-S* were analyzed statistically to determine if any significant difference existed between the 2 pint per 100-gallon concentration and the 1 pint per 100-gallon concentration. *Powell 525* was markedly less effective than *Powell JP25* or *Penco 531-S* at the 2 pints or the 1 pint per 100-gallon concentration not only in the test of July 8 but also in the test of June 8.

Another comparison was made to see if certain DDT sprays (*Cytox* brand) were more effective than DDT dusts (*Cytox* brand). The mortality obtained with the 1 per cent dust was noticeably less than that obtained with the 3 per cent DDT dust or with the Cytox sprays but there was no significant difference between any of the *Cytox* treatments, statistically, at the 5 per cent level.

An evaluation of the different benzene hexachloride preparations (dust, wettable powder, and water miscible) showed that there were no significant differences in effectiveness between them. All of the benzene hexachloride preparations gave a high degree of kill comparable to the average obtained with the various DDT preparations. However, none of the benzene hexachloride preparations had any marked residual power. In one plot, treated with a spray made from a water miscible 30 per cent benzene hexachloride, re-infestation by Colorado potato beetle larvae was noted one day after treatment.

In general, the action of benzene hexachloride upon Colorado potato beetle larvae was much more rapid than that of DDT. Larvae usually remained on DDT dusted foliage for hours before dropping off but on benzene hexachloride treated foliage larvae dropped off immediately after dusting.

Chlordane at the 2 pint per 100-gallon concentration or in combination with DDT gave good control of the larvae. The results obtained with chlordane were not significantly different from the kills obtained with DDT alone.

Pyrenone No. 20 gave the poorest control of any of the compounds used. The knockdown was poor and there was seemingly no residual power and re-infestation of plots shortly after treatment was common.

Unreplicated laboratory treatments, not reported herein, in general approximated the results obtained in the field.

PHYTOTOXICITY.—None of the compounds was responsible for any phytotoxicity when used at the recommended spray concentrations of 1 or 2 pints of emulsion concentrate per 100 gallons water or as dusts of 1 to 5 per cent. Some phytotoxicity was noticed when benzene hexachloride was used far in excess of the recommended concentrations of 1 pint or 2 pints per 100 gallons water.

Tubers, harvested one month after the last treatment, were normal in flavor and odor when cooked or tested raw.

DISCUSSION.—From the results obtained in these tests it was quite apparent

that DDT in the water miscible form used at the rate of one quart of 25 per cent concentrate per 100 gallons water was highly effective for the control of Colorado potato beetle larvae. Although there was no significant difference, between the 2 pints per 100-gallon concentration and the one pint per 100-gallons of the different DDT formulations, it might have been possible to have shown that significant differences did exist had the plot size and number of replicates been increased for each treatment. For the sake of greater residual power it would seem desirable to use the 2 pints per 100-gallon concentrations, thus affording more adequate protection against larvae for a longer time.

The water miscible DDT formulation is more economical to use from the standpoint of actual DDT used than is the dust formulation. If a 25 per cent concentrate is used at the one quart per 100-gallon concentration and applied at the rate of 100 gallons of finished spray per acre, then approximately one-half pound of technical grade DDT is used per acre. Assuming an average application of dust at 30 to 35 pounds to the acre, the amount of actual DDT used in dusting one acre with a 3 per cent dust would be about one pound. For a 5 per cent dust, the actual amount of DDT used per acre would be about 1.6 pounds.

SUMMARY.—Twenty-one insecticidal formulations were used in field tests for the control of Colorado potato beetle larvae. Several water miscible DDT formulations prepared with para-para isomer content of DDT were used. One water miscible DDT formulation had a high content of the ortho-para isomer. Other water miscible formulations contained rotenone, chlordane, or polyethylene pentasulphide, the last being a spray adjuvant. DDT was also used in the wettable powder form and as a 1 per cent and 3 per cent dust. All the DDT formulations, except the one with the high ortho-para isomer content, gave good control of the larvae. The addition of the spray adjuvent did not increase the value of DDT.

Chlordane gave good control of larvae but was not superior to DDT, a piperonyl cyclohexanone-pyrethrum concentrate gave poor control of larvae. Benzene hexachloride gave good control either as a wettable powder, a 5 per cent gamma isomer content dust, or a water miscible formulation but had no great residual power.

No phytotoxicity to potato foliage was noticed with any of the formulations when they were used at the recommended concentrations of 2 pints or one pint per 100 gallons of water. None of the treated potatoes had any insecticidal odor or taste when cooked or raw one month after they were treated.—5-17-47.

LITERATURE CITED

Anon. 1944. New insecticides for potato insect pests. Research and Farming, vol. 3, Progress Report no. 4: 62–3. (67th Annual Report, N. C. Agr. Exp. Sta.)

Bronson, T. E., and F. F. Smith. 1946. Control of aphids on potatoes in northeastern Maine. JOUR. ECON. ENT. 39(2): 189–94.

Dietz, H. F. 1946. Focusing the application of DDT to agriculture. Agricultural Comment (du Pont) 1(1): 1, 4.

Kearns, C. W., Lester Ingle, and Robert L. Metcalf. 1945. A new chlorinated hydrocarbon insecticide. JOUR. ECON. ENT. 38(6): 661–8.

Glasgow, Hugh. 1946. DDT as a control for the pea aphid. JOUR. ECON. ENT. 39(2): 195–9.

Benzene Hexachloride and Chlordane to Control Cotton Boll Weevil[1]

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Benzene hexachloride, chemically termed 1, 2, 3, 4, 5, 6 hexachlorocyclohexane, has been reported as a promising insecticide for the control of the cotton boll weevil and other insect pests of cotton (Ivy & Ewing, 1946; Stevenson & Sheets, 1946). *Velsicol 1068*,[3] a new chlorinated hydrocarbon of the empirical formula $C_{10}H_6Cl_8$, has been tested in the laboratory against several insect pests in comparison with DDT and benzene hexachloride (Kearns *et al.* 1945). Chlordane is probably a mixture of several isomers. It is a viscous and odorless compound soluble in a wide range of organic solvents. The chemical name of this new insecticide is: 1, 2, 4, 5, 6, 7, 8, 8-octachloro-4, 7-methane-3a, 4, 7, 7a-tetrahydroindane.

In order to test the effectiveness of these materials field and laboratory trials were conducted wherein different concentrations of both chlordane and benzene hexachloride were used for the control of the boll weevil, *Anthonomus grandis* Say. The field trials consisted of tests with benzene hexachloride dusts containing 1 and 5 per cent of the gamma isomer. The laboratory tests included benzene hexachloride dusts of 1 to 10 per cent gamma isomer content as well as chlordane sprays and dusts of various concentrations. The field trials are discussed first and separately from the laboratory tests.

FIELD TRIALS.—Field plots treated with benzene hexachloride consisted of four rows of cotton 900 feet long. Treated plots were replicated six times. In addition, there were six untreated 4-row plots which served as checks. Treated plots alternated in position with the check plots and were separated from each other by buffer strips of two rows each. The area under treatment was approximately 10 acres

On July 4 the per cent of egg punctures averaged 8.7 per cent. On July 12 an average of 11.5 per cent of the squares were punctured. A thorough examination of the field on this date showed that the infestation was most severe along the western side of the field and that it diminished noticeably in an easterly direction across the field. Thus the plots, which were run in a north-south direction, included this gradient of the east-west infestation as well as any variation in infestation that existed in a north-south direction.

When treatments were begun, an estimate of the per cent of egg punctures was made in each plot. A total of 100 squares was counted in each 4-row plot. This count was made at the rate of 10 squares in 10 different positions chosen at random within the plot. At the time of this square examination a record was made of the number of weevils observed in each plot. From July 4 to August 21, 1946, the test field was examined nine times. Migration of weevils had occurred by the second week in August and this effected a more even distribution of weevils and egg punctures throughout the entire field. The results of the last three egg puncture counts are presented in table 1.

Treatments were begun on July 12 when egg punctures averaged 11.5 per cent. Four other treatments were made on each of the following dates: July 27, August 3, 9, and 14. A 1 per cent gamma benzene hexachloride dust was used in the first two dust applications. In the last three applications a 5 per cent gamma isomer content dust was used.[1]

The first three applications were made with a 4-row power duster at the rate of 10 pounds to the acre. The other applications were made with a rotary hand duster at the same rate.

Field observations indicated that the 1 per cent gamma benzene hexachloride dust did not give satisfactory control of the weevils and for this reason it was decided to use a 5 per cent gamma isomer dust in the later treatments instead of the 1 per cent dust. The 5 per cent dust was

[1] Contribution from the Department of Zoology & Entomology of the North Carolina Agricultural Experiment Station. Published with the approval of the Director as Paper No. 269 in the Scientific Journal Series.

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[3] The common name "chlordane" has been selected for this material.

[1] Benzene hexachloride dusts were supplied by the California Spray-Chemical Corp. and the Penn. Salt Mfg. Co.

first used on August 3. A square count taken before treatment on August 9 showed an average egg puncture per cent of 24.7. Subsequent dust applications were made on August 9 and 14. The square infestation count on August 16 was 12.2 per cent in the treated plots and 25.7 per cent in the untreated check plots.

A statistical analysis of the results of the later treatments based on the square infestation counts of the last 3 dates of the season (August 13, 16 and 21) is presented in table 1.

DISCUSSION.—The effect of 5 per cent benzene hexachloride dust upon different insects in the field was clearly evident. The results obtained in keeping down the number of boll weevil egg punctures, as shown by the data listed in table 1, were definitely favorable. Unfortunately, the material did not seem to have any marked residual power. The value of an insecticide for boll weevil control is considerably enhanced by residual toxicity.

Table 1.—Number of boll weevil egg punctures per sample counts of 100 squares in treated and untreated plots.

		Egg Punctures					
		Treated plots		Untreated plots			
Date Treated	Date Examined	Range	Average[1] (A)	Range	Average[1] (B)	(B)–(A)	L.S.D.[2]
August	August						
3	13	4–24	15.3	6–49	25.5	10.2	7.3
9	16	6–24	11.5	5–56	31.8	20.3	9.0
14	21	42–58	48.7	62–76	69.8	21.1	9.8

[1] These figures have been adjusted to remove infestation gradient effects.
[2] L.S.D. = Least significant difference at the 5 per cent level.
It should be noted that the observed difference, column B minus column A, is greater than the least significant difference in all cases, indicating that the insecticidal treatment was effective in reducing boll weevil punctures.

The 5 per cent dust produced a quick mortality of insects other than the boll weevil. One day after application, a number of dead insects were observed in the test plots. Listed in the order of their abundance, the following insects were found dead, evidently killed by the treatment: ground beetles, tiger beetles, *Tetracha carolina* (L.), click beetles, wasps, bees and grasshoppers. The ground beetles, tiger beetles and click beetles were more abundant than the others and were found at the rate of 1 to 2 specimens per 25 feet of row.

Some phytotoxicity was observed after the application of the 5 per cent benzene hexachloride dust. In one of the applications, an old model, rotary hand type duster, was used. The mechanism of this duster proved to be faulty and considerable dust leaked out from the fan housing. The dust thus escaping was deposited on the foliage in a well defined strip about 4 inches wide. One day after application the foliage in this 4-inch strip began to turn brown and eventually the leaves died. Other instances of phytotoxicity were observed, especially at the younger and more tender top portions of the plant. A slight excess of dust, such as was deposited when the crank of the duster was given an extra heavy and sudden turn, often caused a discoloration and eventual dying of young leaves and the leaf bracts around the squares.

The sudden increase in the number of weevils toward the latter part of August after the dust treatments were stopped indicates the value of continued dusting to keep down the weevil infestation. It is true that squares this late in the season would not normally develop into mature bolls and, therefore, the value of late dusting for the protection of squares would be questionable. In heavy late infestations, weevils may and do attack the bolls as well as the squares. Therefore, late dusting in areas of heavy weevil populations would be justified because of the protection to bolls. Furthermore, late dusting serves to reduce the number of weevils that go into hibernation and thus reduces the number that can come out of hibernation the next spring.

LABORATORY TESTS.—Benzene hexachloride dusts and chlordane dusts and sprays were used in several laboratory tests for the control of the boll weevil. Various concentrations of both of these materials were used in tests with nearly 3000 boll weevils.

Laboratory trials were conducted according to two different methods of treatment. In the first method, untreated weevils were exposed to the test material contained in a jar but they did not come in contact with the test material. One gram of the test insecticide was placed in a watch glass which was then covered with wire screen cloth so arranged that the weevils could not get into the dust. The watch glass with the test material was placed in a pint size wide mouth fruit jar. The weevils were placed in the jar and the jar was covered with a wire screen cloth top so that the weevils could not escape. The weevils were kept in the jars without food or water for 3 days and checks were made on their activity at 1, 2, 4, 8, 24, 48 and 72 hours after treatment, that is, after the weevils and test material had been placed in the jar. This method of testing is subsequently referred to as method 1.

In the second method of laboratory testing, the dusts or sprays were applied to fresh sprigs of cotton foliage, about 6 inches long. These sprigs had at least two leaves and one square. After treatment the sprigs were placed in fruit jars and the untreated weevils were introduced into the jar. Examinations of the jars were made at the same intervals as stated in the first method of laboratory testing. This method of testing is hereinafter called method 2.

LABORATORY TESTS WITH BENZENE HEXACHLORIDE.—Table 2 lists the results of the various tests with benzene hexachloride. It should be noted that the percentage of the various dust concentrations refers to the percentage of the gamma isomer content of the dust. Treatments with the four different dust concentrations were replicated five times and 100 weevils were used in each treatment. The weevils used in these tests, except where noted otherwise, were collected in the field the day before the test and kept overnight without food or water until they were used the following morning.

The records of the after treatment examinations are presented under 2 different columns headed "K" and "D". Under "K" are listed the number of weevils alive but on their backs and incapable of any coordinated movements. The term "knockdown" or "knocked down" is used to describe these weevils. Usually at 8 to 24 hours after treatment, weevils in this category could move their legs rapidly and made frequent attempts to right themselves. After 24 hours, these rapid leg movements and attempts to right themselves diminished. At 48 to 72 hours, most weevils in this category were quiet and moved only when touched or picked up. In the column headed "D" are listed the number of dead weevils.

The examination of the results obtained with fresh dust by the first method (Table 2, section A) shows that benzene hexachloride was definitely toxic to boll weevils despite the fact that the weevils did not come into actual contact with it. There was an appreciable knockdown of weevils after a 4-hour exposure to the dust. An increase in concentration of the dust generally resulted in a greater number of weevils knocked down. The 1 per cent dust had a knock down of 18 weevils with none dead; the 10 per cent dust, 23 knocked down and 1 dead. One day after treatment the 10 per cent dust showed a knock-down of 64 weevils and a kill of 32 whereas the 1 per cent dust had a greater kill, 40 weevils, but a lower knock-down, 51 weevils. At this time the 2 per cent and 5 per cent treatments did not show much difference in knock-down or kill. Two days after treatment, all treatments, except the check, seemed to be about equal in knock-down and kill. The same was true 3 days after treatment. In the check jars, all weevils appeared normal 8 hours after treatment and at 24 hours only 2 weevils were dead and 21 knocked down. Three days after treatment 33 weevils were dead and 31 knocked down in the check treatment.

In this test there was no significant difference between any of the benzene hexachloride dust treatments either in the number of weevils knocked down or in the number of weevils killed. All benzene hexachloride treatments, however, were significantly better than the check treatment at 8 to 48 hours after treatment.

Table 2.—Knockdown (K) and mortality (D) obtained with different concentrations of benzene hexachloride dust used in different methods of treatment against the cotton boll weevil.

Hours after Treatment	Concentration of Dust (Per cent gamma isomer content)									
	1		2		5		10		Check[1]	
	K	D	K	D	K	D	K	D	K	D
Section A—Method 1—Field-collected weevils exposed to fresh dust (100 weevils per treatment)										
1	0	0	0	0	0	0	0	0	0	0
2	2	0	7	0	4	0	7	0	0	0
4	18	0	17	0	24	0	23	1	0	0
8	46	0	44	0	55	1	53	2	0	0
24	51	40	57	34	60	38	64	32	21	2
48	18	82	21	79	20	80	15	85	29	19
72	9	91	6	94	6	94	4	96	31	33
Section B—Method 2—Field-collected weevils on freshly-treated foliage (100 weevils per treatment)										
1	12	0	11	0	13	0	14	0	0	0
2	31	0	34	0	35	0	41	0	0	0
4	51	0	57	1	57	2	67	2	0	0
8	72	1	76	6	84	2	88	7	5	1
24	64	33	66	32	72	28	74	26	24	8
48	35	65	34	66	36	64	27	73	14	31
72	11	89	17	83	11	89	14	86	18	61
Section C—Method 1—Field-collected weevils exposed to 3-day old dust (100 weevils per treatment)										
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	1	0	0	0	0	0
4	3	0	1	0	1	0	1	0	0	0
8	12	1	8	0	10	0	22	0	0	0
24	37	13	40	8	48	10	61	17	9	2
48	55	32	69	25	59	32	62	36	22	7
72	43	54	54	45	51	49	32	67	13	23
Section D—Method 1—Incubated weevils exposed to fresh dust (40 weevils per treatment)										
1	4	0	10	0	0	0	3	0	0	0
2	7	0	15	0	8	0	10	0	0	0
14	22	10	21	12	22	14	21	13	10	3
24	23	17	17	23	14	26	15	25	19	9
36	6	34	4	36	5	35	7	33	12	23

[1] Treated with a dust diluent only. (*Attaclay*)

The weevils subjected to the second method of treatment (Table 2) showed a quicker response to the various dust concentrations than did the weevils in the first method of treatment. There was a noticeable knock-down of weevils one hour after treatment but no kill was recorded at this time. Slight kill was observed with the 2, 5, and 10 per cent dusts 4 hours after treatment. At this time, the greatest knock-down was with 10 per cent dust, 67 weevils; and the lowest knock-down was with the 1 per cent dust, 51 weevils, whereas the 2 and 5 per cent dusts had the same knock-down, 57 weevils. At 24 hours after treatment, the 1 per cent dust showed the greatest mortality with a kill of 33; the 2 per cent, 32; the 5 per cent, 28; and the 10 per cent, 26. At 48 hours, the 10 per cent dust had the greatest kill. At 72 hours after treatment, the kills with all treatments, except the check were about equal and showed no great differences from the kills obtained by the first method of treatment.

It had been noted that benzene hexachloride, as used in the field tests, did not seem to have any prolonged residual power. The effectiveness of 5 per cent dust applied to cotton in the field did not seem to last for more than 3 or 4 days. In order to check further on the residual power of various concentrations of benzene hexachloride dusts, another series of laboratory tests was conducted with dusts that had been exposed for 3 days. One gram of each of the different dust concentrations was weighed out in a watch glass and left exposed to room air for 3 days. After this period, tests were conducted according to the first method of testing. Weevils used in these tests

were collected the day before they were placed in the test jars. Dust concentrations of 1, 2, 5, and 10 per cent benzene hexachloride were used. An inert dust[1] was used as the check treatment. Each treatment was replicated 5 times and 20 weevils were used for each replicate. All replicates were examined at regular intervals after treatment for weevil activity according to the schedule indicated for the other laboratory tests.

The records made at these intervals and the results obtained are listed in table 2. A comparison of the results obtained in this test with results obtained in the 2 tests where fresh dust was used shows a marked reduction in the effectiveness of benzene hexachloride that had been exposed for 3 days before treatment. Treatment with exposed dust showed very little knock-down and kill of weevils after 8 hours whereas the two other tests had a considerable knock-down as well as a small percentage of kill as early as 4 hours after treatment. The difference between the two first tests and the third test in regard to knock-down and kill was rather marked at 1 to 3 days after treatment. For the sake of comparison, the results obtained with the 1 per cent dust concentration in the 3 different tests are listed in table 3.

Table 3.—Results obtained with the use of benzene hexachloride (1 per cent gamma isomer content) dust in 3 different tests.

Test	Hours After Treatment 24		48		72	
	K	D	K	D	K	D
1. Fresh dust	51	41	18	82	9	91
2. Fresh dust on foliage	64	33	35	65	11	89
3. Dust exposed for 3 days before treatment	37	13	55	32	43	54

The data in table 3 shows that the toxicity of 1 per cent dust exposed 3 days before treatment was definitely less than that of fresh dust. This was also true for the other dust concentrations, including the check treatment with inert dust.

It should be noted that the three laboratory tests already described were executed with boll weevils collected in the field. In a fourth test, weevils reared from infested squares were used. This test was conducted according to the first method of treatment. Egg-punctured squares were collected in the field several days prior to the testing date. These squares were kept on shallow trays in a large enclosed box. Precautions were taken to keep the squares moist and free from fungus diseases, thus assuring conditions under which larvae could develop to maturity. As the weevils emerged, they were used in the tests with fresh dust. The dust concentrations used were similar to those used in the other tests. Each treatment consisted of three replicates using a total of 40 weevils for each treatment. The results of this test are listed in table 2.

In general, the reared weevils reacted more quickly to the different concentrations than did the field-collected weevils. One hour after treatment, this reaction was apparent in all treatments with the reared weevils and was indicated by the greater number of weevils knocked down. Twenty-fours after treatment, there was a higher percentage of mortality among the reared weevils than among the field-collected weevils. These observations would seem to indicate that the reared weevils were not as hardy and were less resistant to the insecticidal treatments than were the field-collected weevils.

Tests with Chlordane.—Laboratory tests with chlordane sprays and dusts were made according to both methods of testing described for the benzene hexachloride tests. In the first test with chlordane the 2 and 5 per cent dusts[2] were used according to both methods of testing. Inert dust was again used as the check material. In the second test, untreated weevils were added to sprigs of cotton that had been sprayed with concentrations of chlordane[3] in water, ranging from 1 part chlordane to 1000 parts water to 1 part chlordane to 100 parts water. In all the chlordane tests, each treatment was replicated five times and 20 weevils were used for each replicate, a total of 100 weevils for each treatment. The weevils used in these tests were collected in the field and handled in the same manner as described before.

At 8 hours after treatment there was no difference in the number of weevils killed with the 2 and 5 per cent chlordane dusts and a dust diluent used according to method 1. At 48 hours after treatment, both the 2 and the 5 per cent dusts

Attaclay. Attapulgus Clay Co., Philadelphia.

[2] Supplied by the Riverdale Chemical Corp., Harvey, Illinois.
[3] Supplied by the Velsicol Corp., Chicago, Illinois.

Table 4.—Knockdown (K) and mortality (D) obtained with different concentrations of Chlordane dusts and sprays and benzene hexachloride dusts used in different methods of treatment against field-collected boll weevils. (100 weevils per treatment.)

Material and Concentration (Dusts)	Hours After Treatment													
	1		2		4		8		24		48		72	
Method 1—weevils exposed to fresh dusts														
	K	D	K	D	K	D	K	D	K	D	K	D	K	D
Chlordane—2%	0	0	0	0	0	0	8	0	49	11	60	35	42	58
—5%	0	0	1	0	2	0	13	0	37	14	56	39	51	49
Check	0	0	0	0	0	0	0	0	2	0	15	9	12	20
Benzene hexachloride—2%	1	0	7	0	17	0	44	0	57	34	21	79	6	94
—5%	0	0	4	0	24	0	55	1	60	38	20	80	6	94
Check	0	0	0	0	0	0	0	0	2	0	15	9	12	20
Method 2—weevils placed on treated foliage														
Chlordane—2%	0	0	7	0	15	0	41	0	60	18	53	45	38	60
—5%	1	0	1	0	15	0	49	0	72	24	57	42	23	76
Check	0	0	0	0	3	0	8	0	14	7	19	37	14	64
Benzene hexachloride—2%	11	0	34	0	57	1	76	6	66	32	34	66	17	83
—5%	13	0	35	0	52	2	84	2	72	28	36	64	11	89
Check	0	0	0	0	3	0	8	0	14	77	19	37	14	64
Sprays														
Ratio of Chlordane to water														
1 1000	1	0	0	0	0	0	1	0	6	0	6	3	12	8
1 500	1	0	0	0	1	0	2	0	10	1	15	7	30	14
1 200	2	0	2	0	4	0	8	0	24	4	42	19	52	32
1 100	1	0	3	0	5	0	12	0	33	3	66	25	39	60
Check (water)	2	0	2	0	2	0	3	0	5	0	5	3	3	6

showed no significant difference in the percentage of weevils killed and knocked down but both dusts were significantly more effective than the check treatment.

The 2 and the 5 per cent chlordane dusts applied to cotton foliage (Method 2) resulted in a higher percentage of kill and in a shorter post-treatment interval than did dusts of the same concentration when the weevils were merely exposed to them (Method 1). The 5 per cent dust was considerably higher in percentage of mortality than the 2 per cent dust at 24 or 72 hours after treatment. Although the 2 and 5 per cent dusts had a higher knock-down and mortality at 8 and 48 hours after treatment than did the check treatment, they did not show any significant difference between themselves.

Weevils placed on foliage sprayed beforehand with different concentrations of chlordane spray showed a range in knock-down and mortality about proportional to the concentration of the spray (Table 4). The range in knock-down was somewhat apparent as soon as 8 hours after treatment and was definitely noticeable 24 hours after treatment. At 48 hours after treatment, there was a significant difference in the number of weevils knocked down and killed at the 1, 0.1, 1, 0.2 and 0.2 per cent concentrations. The 1, 0.5 concentration, though not significantly different from the 1, .10 concentration or the check (water), nevertheless was higher in the number of weevils knocked down and killed 72 hours after exposure.

A comparison of chlordane spray treatments with chlordane dust treatments indicates that the liquid formulations did not produce as rapid and as large a kill as did the dusts. Three days after treatment, however, the 1 per cent chlordane spray had a knock-down and mortality equal to that obtained with the 2 per cent chlordane dust.

CHLORDANE AND BENZENE HEXACHLORIDE DUSTS.—A comparison of the mortality produced by these two materials according to the two laboratory methods of treatment is given in table 4. Only the

2 and the 5 per cent dusts are compared. In the first method of treatment 2 per cent benzene hexachloride dust, 24 hours after treatment, had three times the mortality of the 2 per cent chlordane dust. At the 5 per cent concentration, benzene hexachloride showed over twice as great mortality as did 5 per cent chlordane dust. At 48 and 72 hours after treatment, the 2 and 5 per cent benzene hexachloride dusts produced twice the mortality produced by the 2 and 5 per cent chlordane dusts.

According to the second method of treatment, benzene hexachloride dusts at the 2 and 5 per cent concentrations outranked the 2 and 5 per cent chlordane dusts although not in the same degree as they did by the first method of testing.

SUMMARY.—Benzene hexachloride dust, 5 per cent gamma isomer content, was used in 6 replicated plots for the control of the cotton boll weevil under field conditions in the vicinity of Raleigh, North Carolina. Each plot consisted of four rows of cotton, 900 feet long. Plots were treated five times in the period from July 12 to August 14, 1946. In the July 12 and July 27 treatments, 1 per cent gamma benzene hexachloride dust was used but it did not check the abundance of the second brood weevils emerging at that time. The three other dust applications were made with dust containing 5 per cent of the gamma isomer and these later applications reduced the infestation of weevils considerably.

In the field, the 5 per cent dust did not seem to have any marked residual effect on weevils 3 or 4 days after application. The 5 per cent dust, if used too heavily, burned foliage.

In the laboratory, nearly 3000 weevils were tested with various concentrations of benzene hexachloride dust as well as chlordane dusts and sprays according to 2 different methods of testing. Benzene hexachloride dusts of 1, 2, 5, and 10 per cent gamma isomer content did not show any marked difference in the number of weevils killed at 24 to 72 hours after treatment when the weevils were merely exposed to the dust and did not come in contact with it. According to the second method of testing, weevils were allowed to come in contact with the test materials immediately after they had been applied to freshly cut sprigs of cotton foliage. Up to 8 hours after exposure this method produced a more rapid knock-down and mortality at all concentrations than did the first method of testing, in which the weevils did not come in contact with the test materials.

Tests with benzene hexachloride dusts exposed to room air for 3 days before the introduction of the weevils (according to the first method of treatment) showed that there was a marked reduction in the effectiveness of the dust at all 4 concentrations used.

Chlordane in dust and spray form was also used according to the two different methods of testing. Liquid formulations of chlordane were apparently more toxic to boll weevil than were dust formulations of the same material but the former did not produce as rapid a mortality as did the dusts.

Benzene hexachloride dusts, 2 and 5 per cent gamma isomer content, were more toxic to boll weevils than were chlordane dusts of 2 and 5 per cent concentrations.

LITERATURE CITED

Ivy, E. E., and K. P. Ewing. 1946. Benzene hexachloride to control cotton insects. JOUR. ECON. ENT. 39(1): 38–41.

Kearns, C. W., Lester Ingle, and Robert L. Metcalf. 1945. A new chlorinated hydrocarbon insecticide. JOUR. ECON. ENT. 38(6): 661–8.

Stevenson, W. A., and Louis W. Sheets. 1946. Benzene hexachloride to control bugs on cotton. JOUR. ECON. ENT. 39(1): 81.

PACIFIC SLOPE BRANCH MEETINGS

Dates for the 1948 Annual Meetings for the Pacific Slope Branch of the Association have been set for June 14, 15 and 16. The meetings will be held in Vancouver, British Columbia and the headquarters will be the Hotel Vancouver.

DDT and Benzene Hexachloride for Potato Flea Beetle Control[1]

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Irish potatoes in the Blue Ridge Mountain section of the western part of North Carolina are subject to heavy attacks by the potato flea beetle. All varieties of potatoes are severely attacked, especially varieties such as the Red Bliss and Pontiac. One variety, the Sequoia,[3] well adapted to this area and a high producer, is somewhat resistant to flea beetle attack (Gardner *et al.* 1945). In seasons of very heavy infestations, however the Sequoia will show loss of vigor in its growth with an attendant loss in yield.

Two species of flea beetles are responsible for most of the flea beetle damage to potatoes in this area. The potato flea beetle, *Epitrix cucumeris* (Harris), is present in the field from the time that the foliage breaks through the ground until mid-July. This flea beetle has a wide variety of host plants but the potato is its favorite. The major part of injury to potatoes by flea beetles is caused by this species. The other species of flea beetle attacking potatoes in the Blue Ridge area is the tobacco flea beetle, *Epitrix hirtipennis* Melsh. Metcalf (1909) reporting on this flea beetle as a pest of tobacco, noted that it feeds on any plant of the nightshade family. This species appears in potato fields about mid-July and is present until late August or September by which time potato plants have practically dried up.

The injury caused by the two species is the same. The adults feed on the leaf surface, cutting small depressions the size of a small BB shot, usually in the top surface of the leaf. These depressions may be cut all the way through the leaf tissue. In areas of light infestation the injury caused by this type of feeding is scarcely noticeable. Where flea beetles are abundant, the results of the feeding attacks can be easily seen for the leaf appears as if it were peppered with BB shot holes. Heavy injury of this type reduces the growth and production of tubers and may be responsible for a high reduction in yield. Furthermore, plants heavily attacked become more susceptible to leafhopper attacks and subsequent tip-burn, which may cause premature drying of the foliage.

Most growers recognize the injury done to potato foliage but ascribe this injury not to the activities of the flea beetles, but to blight, dry weather, or some combination of unknown factors.

Potato flea beetle larvae feed on the underground portion of the potato plant, particularly on the tuber. Larval feeding on tubers early in the season is usually overcome by the growth of the tuber. Injury later on in the season and especially after the tuber is half grown is responsible for roughening the surface of the tuber. This disfiguration of the tuber surface may be enough to throw the potatoes out-of-grade. Instances of larval feeding severe enough to bring about this condition have been noticed in several fields during the past three years.

Early experimental trials with 3 per cent and 5 per cent DDT dusts produced remarkable results when compared with the insecticides previously in use (Anon. 1944). As a result of these early tests, DDT dust, 3 per cent or 5 per cent, is now the principal dust used for flea beetle control in the mountain area. Fields that formerly had as many as 500 to 1000 flea beetles per 10 hills of potatoes were found to be practically free from the beetles after DDT dusts had been used. Potato leaflets in untreated fields were often riddled with flea beetle feeding holes at the rate of 100 per square inch of leaf surface. In fields treated with DDT dust, leaflets had as few as two or three holes per square inch of leaf surface.

Such a high degree of plant protection did not come with only one or two dustings with DDT but was the result of a carefully executed insecticidal treatment program. Even with DDT dusts it was

[1] Contribution from the Department of Zoology and Entomology, North Carolina Agricultural Experiment Station. Published with the approval of the Director as Paper No. 258 of the Journal Series.

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[3] Developed by Prof. M. E. Gardner and Robert Schmidt of the Hort. Dept., N. C. Agric. Exp. Sta., in cooperation with the U.S.D.A. as part of the National Potato Breeding Program.

necessary to start dusting as soon as plants were three to four inches high and to continue dusting at weekly intervals until the growth of vines made it impossible to get machinery into the field. In such a dusting program the first dust was applied at about 10–15 lbs. to the acre. The per acre application was gradually stepped up until it reached 60 to 65 lbs. at the time of the sixth to seventh (the last) dusting.

The use of water miscible DDT spray formulations has demonstrated that plant protection from insects can be effected with small amounts of DDT per acre. Potato aphids have been controlled with as little as 0.5 pound of DDT per acre (Bronson & Smith 1946). Pea aphids have also been controlled with small per acre applications of DDT (Glasgow 1946). An interesting feature about these two instances is the use of a suitable solvent which evidently produces a synergistic effect.

Control of the potato flea beetles in the Blue Ridge Mountain area might be possible with light applications of DDT. For this reason, a series of field tests using four different brands of water miscible DDT formulations was planned. In addition, 3 per cent DDT dust was used as well as a wettable form of benzene hexachloride.

The water miscible forms of DDT used in these tests were all supplied by the manufacturers.[1] Each of these materials contained 25 per cent by weight of technical grade DDT except *Penco 531-S*, which contained 32.6 per cent. *Powell 525* concentrate is high in the ortho-para isomer. Each of these four miscible DDT concentrates was used at two concentrations—1 pint to 100 gallons water and 2 pints to 100 gallons water. Only one dust, 3 per cent DDT, was used in these tests.

Benzene hexachloride was used in a suspension at the rate of 11 gm. of 50 per cent (gamma isomer content, 6.0 per cent) wettable powder to a gallon of water.[2]

The four water miscible DDT concentrates at the one pint and one quart per 100 gallons concentrations, the 3 per cent DDT dust, and the benzene hexachloride comprised 10 treatments. Each treatment was replicated four times. Treated plots consisted of four rows, each 40 feet long. Plots were located in an area where flea beetle infestation was severe and where no previous control of potato insects had been attempted. In addition to these treatments, unreplicated treatments with *Powell 525*, *Powell JP25* and *Cytox Emulsion #10* were made on other fields of potatoes severely attacked by flea beetles. The Sequoia variety of potato was used in all test plots.

All sprays were applied with a knapsack type sprayer. DDT dust was applied with a hand rotary type duster. Spray applications were made from mid-morning on, when the dew had dried off the plants. Dust applications were made in the late afternoon or early evening after the wind had died down.

All plots were examined before and after treatment to determine the amount of flea beetle injury and to check on the relative abundance of flea beetles. In addition, observations were made on the abundance and activity of other potato pests, such as the potato aphid and the potato leafhopper.

Pretreatment examination of the plots included a count of flea beetles per ten sweeps over ten hills in each plot as well as a count of flea beetle holes in ten leaflets chosen at random in the two center rows of each plot. The sweeping was made with the same type of net for each sample. Flea beetles collected thus were transferred to a large killing bottle and counted in the field after they died, or if very numerous, they were counted later in the laboratory. The flea beetle hole counts were made at weekly intervals before each treatment. In counting the holes, only one square inch of leaf surface was used. This counting area was selected at random.

The pretreatment sweeping sample and flea beetle hole count gave a good index of the abundance of flea beetles and the amount of feeding being done by the adults. The post-treatment sweeping sample, taken 1 day after treatment, was used as an index of the toxicity of the insecticide. In addition to these checks, observations were made immediately after treatment to observe the effect of the sprays and dust on flea beetle activity.

All plots were treated five times during the season from June 13 to July 28. Flea

[1] Powell and Co. supplied two water miscible DDT preparations labeled *Powell JP25* and *Powell 525;* American Cyanamid Company supplied *Cytox Emulsion #10* and the Pennsylvania Salt Manufacturing Company supplied *Penco 531-S.*

[2] Supplied by the California Spray-Chemical Corporation.

beetle abundance and activity was subnormal until the early part of July, when there was a tremendous increase in all plots. In mid-July the number of flea beetles per sample of 10 leaves ranged from 745 to 963 (total of four replicates). The pretreatment infestation records of July 18 are regarded as typical of the infestation present in the experimental plots. These infestation records, along with a listing of the treatments, the percentage reduction in number of flea beetles one day after treatment and the sample counts of flea beetle holes are presented in table 1. None of the concentrations used produced any phytotoxicity.

Table 1.—Pre- and post-treatment record of flea beetles and flea beetle holes, treatment of July 18, 1946.

Material	Pints per 100 Gals. Water Pints	Before Treatment		1 Day after Treatment	Per Cent Reduction
		Flea Beetles	Flea Beetle Holes	Flea Beetles	
Powell JP 25[1]	2	612	751	72	88.2
Powell JP 25	1	589	895	58	90.2
Powell 525[1]	2	687	817	89	87.0
Powell 525	1	692	844	92	86.7
Penco 531-S[2]	2	604	879	46	92.3
Penco 531-S	1	826	963	54	93.4
Cytox Emul. #10[1]	2	715	865	74	89.7
Cytox Emul. #10	1	692	906	55	92.1
DDT—3 per cent dust		634	745	184[4]	70.9
Benzene hexachloride[3]	110	779	958	40	94.9

[1] Water miscible 25% DDT concentrate.
[2] Water miscible 32.6% DDT concentrate.
[3] Wettable powder containing 6% gamma isomer.
[4] Post-treatment count of flea beetles made 2 days after treatment instead of the usual 1 day after treatment.

Observations on the control of flea beetles during the past three seasons have indicated the value of hole counts and sweeping samples in checking the effectiveness of insecticidal treatments. These observations are corroborated in part by a review of the data presented in table 1. The lessened flea beetle attack can be acribed to the effectiveness of the insecticidal material used for control. The effectiveness of the insecticide is important not only in its immediate action upon flea beetles but also in its residual power, which protects the foliage from repeated attacks of new hordes of flea beetles.

In table 1, it will be noted that foliage dusted with 3 per cent DDT showed, at the end of the season, fewer flea beetle holes than any of the other plots. Foliage treated with *Powell JP25* at the 2 pints to 100-gallon concentration was next in line with 751 holes per sample of ten leaflets, only six above that of the 3 per cent DDT dusted plots. *Powell 525* at the 2 pints and the 1 pint to 100 gallons concentration ranked next in the number of holes. The largest number of holes was recorded from the benzene hexachloride plots, 958 holes, and the 1 pint to 100 gallons concentration of *Penco 531-S*, 963 holes. These figures indicate that the 3 per cent DDT dust had the greatest residual effect and that benzene hexachloride and *Penco 531-S*, at 1 pint to 100 gallons had the least residual effect of the compounds tested.

A reduction of 90 per cent of flea beetles was noticed in all treatments within one-half hour after treatment. Checks at intervals of 1 to 6 days after treatment showed that there was a gradual increase in flea beetles in all plots, indicating that none of the treatments, except the 3 per cent DDT dust treatment, possessed any marked residual toxicity. A comparison of the water miscible DDT treated plots with a field undergoing a regular DDT 3 per cent dust treatment program showed that the dust treatment was holding down the flea beetle population much more efficiently than the liquid DDT treatments. At no time did a sweeping sample number more than 50 flea beetles in the dust treated field whereas the samples from liquid DDT treated plots had two to three times as many flea beetles. This difference was also shown by the flea beetle hole counts which, in the commercially dust treated area, averaged only one-tenth that of the spray treated plots.

Sweeping samples, as indicated before, were a good means of checking on the effect of the insecticides up to one or two days after treatment. After two days, the influx of flea beetles was quite rapid and beetles were abundant in all the plots. The pretreatment count of July 18 taken 10 days after the previous treatment is presented in table 1. Despite the unusual length of time since the last treatment, some of the treated plots showed a considerable variation in the number of flea beetles per sample of ten sweeps. The number ranged from a low to 589 and 604 beetles in the *Powell JP25*, 1 pint to 100 gallons and *Penco 531-S* 2 pints to 100

gallons treatments, respectively, to 826 in the *Penco 531-S* 1 pint to 100 gallons treatment. This variation may be due to factors other than the residual power of the previous insecticidal application. The presence of tall weeds in some of the plots may have had some influence on flea beetle activity by serving as a protective cover for the potato foliage.

DISCUSSION.—The resistance of the Sequoia potato foliage to insect attack is quite striking especially when the Sequoia is grown alongside a less resistant variety such as the earlier maturing Red Bliss. Planted at the same time, both varieties will come up to about the same time and be equal in their growth and appearance until they reach a height of about four to six inches. At this time the Sequoia surpasses the Red Bliss in growth and vigor and its foliage appears heavy, thick and lustrous. Red Bliss foliage appears thin, shows up flea beetle injury well and, in periods of dry weather, becomes somewhat wilted. At any time during the season, flea beetle populations may be the same in fields of Red Bliss and Sequoia but it will be the Red Bliss that will first show signs of injury.

Despite its apparent resistance to insect attack, the Sequoia can be hard hit by the proper combination of flea beetles, leafhoppers and dry weather. Lack of proper insect control in many small garden areas in the Blue Ridge has shown this to be true. Given the protection of adequate insecticidal applications, the Sequoia can pull through heavy flea beetle attacks and will be in better shape to withstand adverse weather conditions.

Although dusting is the accepted method of treating potatoes in this area, there may be an advantage in spray treatments. Hitherto, dust treatments have been used in a combination insecticide-fungicide application. Copper has been used as the fungicide and has resulted in fair but not always satisfactory control of the potato blights, according to reports received from some growers. It is felt that the inadequacy of a dust insecticide-fungicide combination has been due to incomplete coverage of the plant by the dust. A spray treatment, properly applied, might overcome this difficulty and give better control of blights because of the more complete coverage.

SUMMARY.—Two species of flea beetles are ranked among the most destructive insect pests of potatoes in the Blue Ridge Mountain area of North Carolina. These flea beetles are: the potato flea, *Epitrix cucumeris* (Harris), and the tobacco flea beetle, *E. hirtipennis* Melsh. The former is present in the field from May to mid-July; the latter becomes numerous by mid-July and attacks potato foliage until the crop is harvested. All varieties of Irish potatoes commonly grown in the Blue Ridge are attacked but the Sequoia is more resistant to flea beetle attacks than the Red Bliss or the Pontiac.

Control tests with four water miscible DDT concentrates, a 3 per cent DDT dust, and a wettable powder form of benzene hexachloride were made against the potato and tobacco flea beetles. The percentage reduction in number of flea beetles one day after treatment was about equal for all the different insecticides tested. There was no significant difference in toxicity between the one pint and 2 pints per 100 gallons concentrations of the four water miscible DDT concentrations. The 3 per cent DDT dust seemed to have a greater residual toxicity than did any of the water miscible DDT sprays or the benzene hexachloride spray.—5-17-47.

LITERATURE CITED

Anon. 1944. New insecticides for potato insect pests. Research and Farming (N. C. Agr. Expt. Sta. 67th Ann. Rpt.) 3 (Progress Report No. 4): 62–3.

Bronson, T. E., and F. F. Smith. 1946. Control of aphids on potatoes in northeastern Maine. JOUR. ECON. ENT. 39(2): 189–94.

Gardner, M. E., Robert Schmidt and F. J. Stevenson. 1945. The Sequoia potato: a recently-introduced insect-resistant variety. The Amer. Potato Jour. 22(4): 97–103.

Glasgow, Hugh. 1946. DDT as a control for the pea aphid. JOUR. ECON. ENT. 39(2): 195–9.

Metcalf, Z. P. 1909. Insect enemies of tobacco. N. C. Dept. of Agric., Special Bul. Supp. to Oct. Bul., 1909.

Baits to Control Green June Beetle Larvae in Tobacco-Plant Beds[1]

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Larvae of the green June beetle, *Cotinis nitida* (L.), are serious pests of tobacco-plant beds. The larvae (Fig. 1) crawl on their backs and are commonly called grubs. They live in burrows several inches below the soil surface and feed only on the decaying organic matter in the soil, but they frequently come to, or near, the surface to feed. The tunneling and burrowing of the larvae uproot and kill tobacco plants, and severe infestations often completely ruin the plant bed. The damage to plant-bed plants is illustrated in figure 2; a normal plant bed is shown in the same figure.

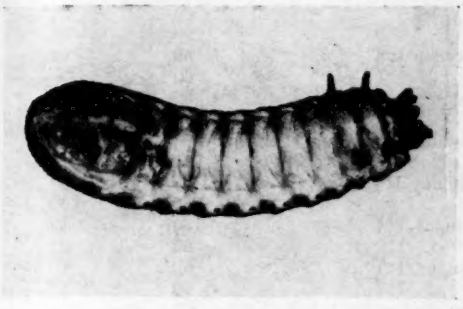

FIG. 1.—Green June beetle larva about two-thirds grown. (Enlarged)

Most of the treatments recommended for the control of grubs are for lawns or golf greens. The treatment most commonly used for tobacco beds consists of a poisoned bait composed of 1 pound of paris green and 25 pounds of wheat bran, moistened with water, and broadcast at the rate of 12 pounds (dry weight) per 100 square yards. This bait was first recommended by McKinney & Milam (1926), and its use was found by Jewett (1943) to be one of the most effective control methods tested.

The control obtained with this bait, however, has varied from year to year, from locality to locality, and even in the same locality during a given season. Because of these inconsistent results the Bureau of Entomology and Plant Quarantine began experiments at Florence, S. C., in 1941 to determine the value of the paris green-wheat bran bait and, if possible, to develop more satisfactory control methods. Experiments have been conducted as follows: (1) Tests were made in the greenhouse during the winter months of the first two years to determine what insecticides and carriers should be tested in the field; (2) tests were conducted on small field plots of infested soil to determine the relative toxicity of different treatments; and (3) those treatments that gave the best results in the small-plot work were tested further on growers' farms where larvae were uprooting old bed sites during the fall or growing plants in plant beds in the spring.

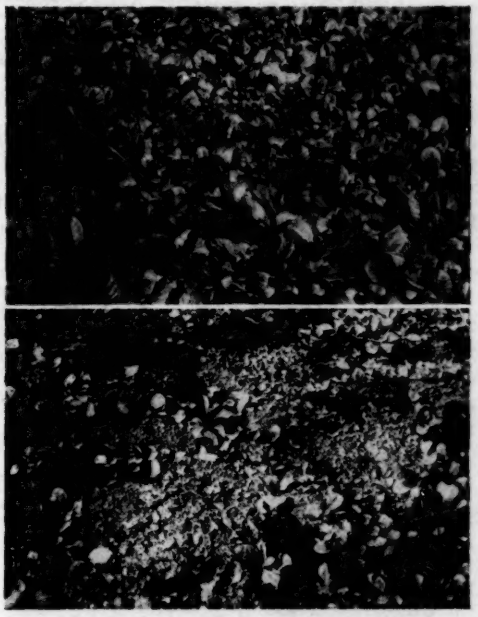

FIG. 2 Above.—Portion of a tobacco-plant bed showing normal plant growth.
Below.—Portion of a tobacco-plant bed where the plants have been destroyed by the burrowing of green June beetle larvae.

GREENHOUSE Experiments.—For these experiments cypress lumber was used to construct boxlike beds 6 feet long, 2 feet

[1] In cooperation with the South Carolina Experiment Station

wide, and 6 inches high. The beds had wooden bottoms, and the tops were left open so that cloth could be stretched over them. Each box was divided into 12 approximately equal compartments by cypress boards of the same height as the sides of the box. Two gallons of clean builders' sand, which had been passed through wire screen to remove any larval partments, and the dead and living were counted.

When the greenhouse tests were begun, only two compartments were used for each bait, but it was soon apparent that too few replications were being used. Therefore further tests were made using a randomized block with six replications for each treatment.

Table 1.—Comparative effectiveness of paris green baits containing various carriers against green June beetle larvae in greenhouse experiments. (Except where indicated, 25 pounds of carrier was used with each pound of paris green.)

Carrier	Bait per 100 Square Yards	Sweetening Agent or Water[1]	Total Larvae	Average Mortality
	Pounds		*Number*	*Per Cent*
Corn meal	9	None (dry)	62	24
		Water	59	23
		Syrup and water 1:1	56	39
		Syrup	180	59
		Blackstrap molasses:		
		2.5 pt.	60	30
		5 pt.	60	32
	18	Syrup	298	63
		Water and syrup 1:3	59	62
		1:1	60	60
		Syrup 2.5 pt.	60	45
		Cane syrup	179	56
		Water and white corn syrup 1:1	60	65
		White corn syrup	60	70
		Water and honey 1:1	60	57
		Honey	59	55
		Water and sugar 1:1	180	58
		1:2	59	71
		Syrup and sugar 1:1	60	60
		1:2	60	67
		Water, syrup, and sugar 1:1:1	60	68
		Sugar and corn meal 2:1	59	44
		1:2	60	47
Corn meal[2]	9	Syrup	60	58
Wheat bran	18	Syrup	60	45
Cottonseed meal	18	Syrup	59	48
Untreated checks	—	—	299	4

[1] Unless otherwise indicated, 5 pt. to 25 lb. of carrier. A mixture of corn and cane syrup was used except where otherwise indicated.
[2] 2 lb. of paris green to 25 lb. of corn meal.

food, was put in each small compartment, together with 10 large green June beetle larvae obtained from infested soil. After the larvae had entered the sand, a small can with a perforated bottom was used to sprinkle an equal quantity of water into each compartment.

Each material tested was weighed or measured and then mixed by hand. A weighed quantity of bait was sprinkled over the soil surface of each small compartment, usually at a rate equivalent to 18 pounds (wet weight) per 100 square yards. At the conclusion of each test all the larvae were removed from the com-

The first tests showed that (1) 1 pound of paris green to 25 pounds of carrier was a lethal concentration, although the mortality was low, possibly because the larvae were exposed to the bait for only 5 nights; (2) lead arsenate and tartar emetic were of very little, if any, value in baits; (3) horse manure, owing to the difficulty of securing and applying a good mixture, was not superior to wheat bran; (4) the addition of bananas, oranges, or peaches to the bait did not increase larval mortality; and (5) corn meal was promising as a carrier for paris green when syrup was added.

As a result of these findings, five replicated experiments were conducted to compare the value of various quantities of water, a commercial blend of corn and cane syrup, cane syrup, honey, and sugar when these were added to the paris green-corn meal bait. A brief summary of these experiments is given in table 1. These experiments showed that green June beetle larvae fed readily on baits containing syrup, sugar, or a commercially prepared white syrup, and to a lesser extent on blackstrap molasses. The most consistently effective bait tested consisted of 1 pound of paris green, 25 pounds of corn meal, and 5 pints of syrup.

Table 2.—Comparative effectiveness of paris green baits containing various wheat products as carriers against green June beetle larvae in greenhouse experiments. (25 pounds of carrier was used with each pound of paris green.)

Wheat Product	Total Larvae	Average Mortality
	Number	*Per Cent*
Regular products:		
Bran	60	42
Middlings	180	62
Shorts	60	77
Whole-wheat flour	60	75
Bran:[1]		
Small	60	53
Medium	240	56
Large	240	48
Middlings:[1]		
Small	59	71
Large	60	63
Mixtures (1:1):		
Bran and middlings, both regular	120	52
Bran, large, and middlings, regular	120	66
Bran, large, and shorts, regular	120	41
Checks:		
Middlings, regular, and cane syrup	60	72[1]
Corn meal and cane syrup	241	52[2]
Untreated	238	9

[1] Small indicates that the product passed through a 40-mesh sieve; medium, through a 16-mesh sieve; and large, not through a 16-mesh sieve.

[2] The high mortality obtained in this test was never verified in subsequent tests.

A plant-bed experiment in 1941 showed that the paris green-wheat bran bait used was much more effective than supposedly identical baits used in the greenhouse. An investigation showed that this wheat bran probably contained middlings, hence it seemed advisable to test various wheat products as carriers for paris green. Accordingly, wheat bran, wheat middlings, and wheat shorts were obtained from a mill where they had been separated by hand, and used in baits containing paris green. The baits were applied at a rate equivalent to 18 pounds (wet weight) per 100 square yards, and the larvae were examined after having been exposed for five nights. This experiment showed that paris green mixed with wheat middlings, wheat shorts, equal parts of bran and middlings, or equal parts of bran and shorts killed approximately twice as many larvae as did bran alone with the poison.

Since this experiment indicated that the larvae preferred wheat products other than bran, and since the particle size of all those materials used was smaller than that of bran, it seemed worthwhile to compare particles of different sizes, particularly of bran and middlings. For this purpose four randomized-block experiments were conducted in the greenhouse during the winter months of 1942. Seven treatments and an untreated check, each replicated six times, were used in each experiment. The results are summarized in table 2. It will be noted that higher mortalities were obtained with small to medium-sized particles than with large particles of the same material; however, the larvae evidently preferred middlings, shorts, and even whole-wheat flour, to wheat bran. Moreover, even though wheat shorts, for example, made a poor physical mixture with water, it was nevertheless effective. Water was used to prepare all baits, except where syrup is mentioned.

SMALL FIELD-PLOT EXPERIMENTS.—Border boards that are ordinarily used for plant beds were used for the sides of all test areas. In addition, boards 5 to 6 inches wide were used to construct 0.5 square-yard compartments, or plots, throughout each test area, and these boards were sunk about 4 inches into the soil to reduce the interplot movement of the larvae. Larvae were collected from farms and transplanted in the test areas during October of each year from 1941 to 1945. Equal numbers of larvae were placed in each small compartment, these numbers ranging from 25 to 60 in different years. An abundance of barnyard manure was placed in each compartment as larval food, and the larvae were allowed to become well established before the experiments were begun.

When an experiment was begun, the

manure was removed from all test areas except the checks. Each plot was sprinkled with water before a bait was applied. Sprinkling apparently increased the burrowing activities of the larvae and therefore increased their chances of obtaining the bait. All materials were randomized and replicated from 4 to 8 times by using the 0.5-square-yard areas of infested soil. From 1941 through 1943 eight replications were made of each treatment, but from 1943 through 1945, owing to a manpower shortage, each treatment was replicated only 4 times. As a rule 7 treatments and an untreated check were used for each test, therefore during the first three years there were 64 plots in each experiment and during the last two years there were only 32.

Each material tested was weighed or measured and then carefully mixed by hand.[2] The quantity of bait for each compartment was weighed and sprinkled over it at a rate equivalent to 18 pounds (wet weight) per 100 square yards. When the experiments were begun, the treatments were exposed to the larvae for 5 to 9 nights; however, during 1945 one experiment was left undisturbed for 27 nights. At the conclusion of each experiment soil containing the larvae was excavated from each compartment, and the dead and living were counted. Owing probably to the type of soil used, it was necessary to excavate the soil to a depth of 10 to 14 inches. The control was based on actual larval recovery for a given treatment, although a series of check plots was used for each experiment.

Results of 16 replicated small-field-plot experiments have been briefly summarized in table 3. Although the work extended over a 5-year period and the tests were conducted from February 14 until May 19, the data obtained for a given insecticide have been combined so that different quantities of the same insecticide as well as different insecticides can be compared. This method of presentation fails to show the variation in different tests, but it does make comparisons easy.

These experiments showed that (1) in general, wheat middlings, wheat shorts, and even wheat products sold as hog feed were more effective carriers for insecticides than was wheat bran; (2) wheat shorts, even though giving good larval mortality, made a poor physical mixture; (3) the most effective insecticides tested were barium, sodium, and potassium fluosilicates; (4) the bait composed of paris green, corn meal, and syrup, developed in the greenhouse, was not entirely satisfactory in plant beds, because it became dry and crumbly, and therefore unattractive, when placed under plant-bed covers during warm, dry weather; and (5) sodium arsenite, cube, pyrethrum, basic copper arsenate, and cryolite either were avoided by the larvae or were not sufficiently toxic to give satisfactory control.

EXPERIMENTS ON GROWERS' FARMS.—Baits containing paris green and wheat bran; paris green, corn meal, and syrup; paris green and wheat middlings; and either barium, sodium, or potassium fluosilicate and wheat middlings were tested for the control of green June beetle larvae in beds of growing plants. Owing to the impossibility of the treated areas being excavated, the results of these experiments were not accurate. However, frequent counts of larval burrows showed that the larvae were being killed. Best results were obtained with the fluosilicate baits. Supplying the baits to the burrows, or to the burrowed area, was about as effective as broadcasting it, and less bait was required. The paris green baits were not only less effective than the fluosilicate baits, but unless carefully applied under favorable conditions they will seriously damage tobacco plants, especially if broadcast over small plants.

In addition to the experiments in beds of growing plants, the barium fluosilicate-wheat middlings bait has been tested as a control when applied to infested plant-bed sites during the fall months. One application of this bait gave excellent control when broadcast over severely infested areas at a rate of 20 pounds (wet weight) per 100 square yards. The treated areas when seeded to tobacco produced a good stand of healthy plants.

DISCUSSION.—All greenhouse and small-plot experiments were planned and executed so that an analysis of variance of the percentage of mortality could be made for each experiment. From these analyses could be determined not only the best treatments but, more important to the investigators, the consistency of the results from a given bait either during one season or during different years. By planning the experiments so that every plot contained about the same number of lar-

[2] Analyses of materials were supplied by the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine, except that of the proprietary material, which was supplied by the manufacturer.

Table 3.—Comparative effectiveness of various baits against green June beetle larvae in small-field-plot experiments.

Poison	Carrier[1]	Poison in 25 Parts of Carrier	Plots Used	Total Larvae	Average Mortality
		Parts	*Number*	*Number*	*Per Cent*
Barium fluosilicate (70.6% $BaSiF_6$) and sodium fluoaluminate (7.8% Na_3AlF_6)	Middlings	4	4	86	71
		5	4	70	97
Barium fluosilicate (99.2% $BaSiF_6$)	Bran	4	8	217	82
	Middlings	1	8	215	51
		2	16	356	81
		3	8	187	84
		4	28	683	89
		8	8	221	92
	Shorts	4	8	200	86
Copper arsenate, basic (38.4% As_2O_5 and 54.6% CuO)	Middlings	1	8	176	7
		2	8	163	11
Cryolite (94.8% Na_3AlF_6)	Middlings	1	8	111	23
		2	16	317	49
		3	8	136	36
		4	8	104	40
Cube (4.7% rotenone)	Middlings	1	8	188	2
Paris green	Corn meal	1[2]	30	614	56
		1[3]	24	394	56
	Bran	1	54	838	55
		2	16	249	78
	Middlings	1	90	1530	66
		2	32	611	77
		3	8	119	82
		4	8	94	85
	Shorts	1	22	343	70
		2	8	140	87
	Shipstuff[4]	1	16	292	65
	Whole-wheat flour	1	16	164	46
		1[2]	8	91	27
Potassium fluosilicate (80.9% K_2SiF_6) micronized	Middlings	4	8	234	92
Pyrethrum (0.9% pyrethrins)	Middlings	1	8	100	20
Sodium arsenite	Middlings	1	8	238	21
		2	8	198	33
Sodium fluosilicate	Middlings	2	8	176	83
		4	8	194	84
Untreated checks		—	90	1482	4

[1] All carriers were wheat products, except where corn meal is mentioned.
[2] Plus a commercial blend of corn and cane syrup. All syrups used in the proportion of 5 pints to 25 pounds of carrier.
[3] Plus cane syrup.
[4] A commercial mixture of wheat products containing protein 14, fat 3.25, fiber 8.5, and carbohydrates 62 per cent.

vae for a given test, and then by adequately replicating each treatment, it was possible to obtain consistent results with a given bait. An example of the consistency is shown in table 4, where paris green and wheat middlins 1–25 was used in nine experiments conducted from 1941 through 1944. Despite the fact that the rainfall for individual tests ranged from none to 3.25 inches and the mean air temperature from 52° to 75° F., the larval mortalities ranged only from 61 to 77 per cent with an average of 67 per cent. These results agree closely with previous findings (Allen & Pollard 1941) as well as with the results from tests with this bait shown in table 3.

Experiments conducted in the greenhouse and in the field showed that green June beetle larvae fed readily on baits and that they would consume certain insecticides and carriers in preference to others. Those carriers that gave the highest mortalities were considered to be preferred by the larvae; however, it is realized that more particles of the insecticide may have adhered to such carriers. Why certain very poisonous insecticides such as sodium arsenite killed so few larvae is not known unless the larvae avoided it. Lead

arsenate, basic copper arsenate, cryolite, cube, and pyrethrum either were avoided by the larvae or were not sufficiently toxic to give satisfactory control.

Table 4.—Mortalities of green June beetle larvae at different times to bait composed of paris green and wheat middlings 1:25.

Period of Exposure	Mean Temperature	Total Rainfall	Total Larvae	Average[1] Mortality[1]
	° F.	*Inches*	*Number*	*Per Cent*
April 14 to 19, 1941	75	0	57	72
May 12 to 23, 1941	75	.02	83	64
March 19 to 27, 1942	56	1.54	133	68
March 28 to April 6, 1942	53	.35	146	77
April 8 to 16, 1942	62	3.25	84	69
March 20 to 30, 1943	52	3.20	150	65
March 25 to April 10, 1943	58	2.02	146	66
April 13 to 22, 1943	54	.61	221	61
April 15 to 22, 1944	67	.30	67	61

[1] Average for 8 replications in all experiments except the first one in 1941, where there were 6 replications, and one in 1944 where there were only 4 replications.

Results obtained with paris green and different wheat products led the authors to believe that variation obtained with the paris green-wheat bran bait, either by different investigators or by the same investigator during a given season, may have been due largely to differences in the composition of the wheat bran the investigator used, or in the length of time the bait was exposed to the larvae. Repeated tests have shown that the various wheat products differ in effectiveness and that the most effective bait must be exposed to the larvae for at least 1 week for maximum efficiency.

The experiments showed that the effect of rains on a bait is of less importance than is generally supposed. Although heavy rains will wash a bait away, light rains will effect better results from the bait, probably because they increase the burrowing activities of the larvae.

SUMMARY.—Larvae of the green June beetle, *Cotinis nitida* (L.), are serious pests of tobacco plant beds. Because of the variation in their control obtained with a paris green-wheat bran bait, extensive greenhouse and field experiments were conducted between 1941 and 1945 to develop a better control method.

In experiments with various carriers for poisoned baits, wheat middlings, wheat shorts, and equal parts of bran and middlings were more effective than wheat bran. The wheat middlings, sold, frequently as hog feed, made the best physical mixture. The addition of sweets to the wheat middlings did not increase the effectiveness of the bait.

The fluosilicates were the most effective insecticides tested in baits. A bait composed of 4 pounds of barium, sodium, or potassium fluosilicate, 25 pounds of wheat middlings, and 2 to 2.5 gallons of water, when exposed to the larvae for at least 1 week, killed about 9 out of every 10 larvae present. This bait not only proved effective in beds of growing plants but was the most effective treatment when broadcast over severely infested bed sites during the fall months.—6-9-47.

LITERATURE CITED

Allen, N., and H. N. Pollard. 1941. Control of green June beetle larvae in tobacco plant beds. S. C. Expt. Sta. Ann. Rpt. **54**: 123–7.

Jewett, H. H. 1943. Control of green June beetle larvae *Cotinis nitida* (L.) in tobacco beds. Ky. Agr. Expt. Sta. Bul. **445**.

McKinney, K. B., and Joe Milam. 1926. The green June beetle larvae in tobacco plant beds. U. S. Dept. Agr. Farmers' Bul. **1489**.

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The Effect of Husk Extension and Tightness on Earworm Damage to Corn[1]

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Husk extension has been considered a major character in protecting ears of corn from damage by the corn earworm, *Heliothis armigera* (Hbn.). Many references to this protection are found in the literature. Usually the statement is made that the long husk affords protection from both the earworm and the rice weevil, *Sitophilus oryza* (L.).

Work on resistance of corn to the corn earworm has been conducted in Mississippi since 1943 by the Bureau of Entomology and Plant Quarantine, in cooperation with the Mississippi Agricultural Experiment Station and the Bureau of Plant Industry, Soils, and Agricultural Engineering. In that year the late John C. Hamlin planted two nurseries, one at State College and one at Stoneville. These nurseries were harvested by T. R. Chamberlin and W. A. Douglas. The inbreds used in these nurseries were mostly from Kyle's Long Season Synthetic, and were apparently selected on the basis of husk extension beyond the tip of the ear. Many of the inbreds had husk extensions of 4 to 8 inches and, since even these were badly damaged by the earworm, it seemed unlikely that husk extension could be relied on to protect corn from earworm damage.

As the work with different kinds of corn progressed, it became evident that a long husk extension would not protect corn from the earworm. In studying the various types of corn in a search for evidence of resistance to the earworm, it was found that certain varieties of hybrids with short or medium husk extensions have more resistance than certain other varieties or hybrids with husk extensions that are long and tight. Various methods have been used to study the effect of husk extension on earworm resistance, and some of them will be briefly described in this paper.

Inbreds.—The inbreds studied consisted of Kyle's Long Season Synthetic and of Florida, Texas, Illinois, Kentucky, Missouri, Indiana, Tennessee, Louisiana, and U. S. lines. The Kyle's Long Season Synthetic and the Florida lines were included because of their long husks, whereas others, such as the Texas, Kentucky, Illinois, Kansas, Missouri, Indiana, and Tennessee lines, were not expected to have long husk extensions. The data obtained from all ears on 10 inbreds were arranged and averaged according to husk length (Table 1). Increasing tightness of husk and increasing earworm infestation were estimated on an arbitrary scale from 0 to 5. The most important features of this table are the uniformity of earworm grades among the lots of ears with different husk extensions, and the increase in tightness of the husk as the total length of husk and the husk extension beyond the tip of the ears increased. The uniform length of ears in all husk lengths is probably characteristic of the inbreds used in the tests.

Table 1.—Relation of ear length, total husk length, tightness of husk, and length of extension beyond the ear tips to average corn earworm damage in 10 inbred lines grown in plots in Mississippi, 1943.

Total Ears Examined	Ear Length	Total Husk Length	Husk Extension	Husk Tightness	Earworm Damage
Number	*Inches*	*Inches*	*Inches*	*Grade*	*Grade*
90	6.0	7.0	1	0.9	2.75
93	6.2	8.2	2	1.3	2.71
83	5.6	8.6	3	1.8	2.59
101	5.4	9.4	4	1.9	2.62
91	6.1	11.1	5	2.7	2.77
79	5.8	11.8	6	2.9	2.39

Hybrids and Open-Pollinated Varieties.—Data were obtained on husk extension in relation to earworm resistance in all available material in experimental plantings at different Mississippi localities in 1944. Each test consisted of approximately 25 entries with 6 replications. In table 2, however, only those having the best and poorest husks are included. Average husk lengths for the corn varieties or hybrids having the three longest husk extensions and for those

[1] Cotton States Branch Program.

[2] In cooperation with the Bureau of Plant Industry, Soils, and Agricultural Engineering and the Mississippi Agricultural Experiment Station.

Table 2.—Earworm resistance of corn varieties in relation to husk characters, main hybrid tests at different locations in Mississippi, 1944.

Variety	Average Husk Extension	Average Husk Tightness	Earworm Resistance
	Inches	*Grade*	*Rank*
Holly Springs			
Florida W1	3.8	3.8	5
Tuxpan	3.0	3.0	12
Yellow Whatley	2.8	2.8	3
Whatley Prolific	2.8	2.8	8
Hills Yellow Dent	2.8	2.8	17
La. Hy. 3802	2.0	1.8	7
Jellicorse	2.0	1.8	20
Tenn. Hy. 10	2.0	1.7	19
N. C. Hy. 4004	2.0	1.7	8
West Point			
Florida W1	5.8	4.0	4
Yellow Whatley	4.3	4.0	5
Tenn. Hy. 10	3.0	2.8	20
Hastings Yellow Prolific	2.8	2.7	8
Tenn. Hy. 15	2.8	2.5	10
Stoneville			
Florida W1	3.8	3.8	16
Hills Yellow Dent	3.3	3.3	20
N. C. Hy. 4026	3.2	3.2	6
Funk G714	2.0	1.7	20
N. C. Hy. 4003	1.8	1.8	9
Tenn. Hy. 5	1.8	1.8	20
Raymond			
Florida W1	4.7	4.0	12
Yellow Whatley	3.7	3.5	3
Hills Yellow Dent	3.5	3.5	14
N. C. Hy. 4025	2.2	1.8	11
Tenn. Hy. 15	2.0	1.7	20
Tenn. Hy. 10	2.2	1.3	22
Natchez			
Florida W1	4.0	3.8	1
Whatley Prolific	3.5	3.3	6
Tuxpan	3.5	3.0	11
N. C. Hy. 4004	1.8	1.0	15
Tenn. Hy. 15	1.7	1.2	25
Tenn. Hy. 10	1.3	1.0	24
Poplarville			
Mosby	4.0	3.3	5
Florida W1	4.0	3.2	7
Florident Yellow	4.0	3.0	11
Laguna	1.7	1.2	22
Tenn. Hy. 15	1.3	1.3	20
Tenn. Hy. 10	1.2	1.0	18

having the three shortest are given in this table, together with their husk tightness and their rank for earworm resistance among all the entries. The data are shown separately for each station at which observations were made.

At Holly Springs the hybrid Florida W1 had the greatest husk extension and tightness, but ranked fifth in earworm resistance. Tenn. Hy. 10 and N. C. 4004 had the least husk extension and tightness, but ranked nineteenth and eighth, respectively, in earworm resistance. It may be observed also that Whatley Prolific, with the third longest husk extension, ranked only eighth, but that La. Hy. 3802, with the shortest husk, ranked seventh.

In most of the tests the variety with the greatest husk extension and tightness did not have the lowest earworm injury, although it may have ranked among the lowest, and the variety with the least earworm injury was not among those with either the longest or shortest husk extension. This variable preformance is evident throughout the main hybrid and variety tests at all the stations. Florida W1 had the longest husks at most locations, yet its rank for earworm injury ranged from first to sixteenth.

The correlation between husk extension and earworm injury within commercially grown varieties and hybrids was also studied. In these studies it was assumed that all ears of a single variety or hybrid had the same inherent resistance, and that any difference in amount of earworm damage might be definitely correlated with length of husk extension.

Corn from 10 cribs in the vicinity of State College was used in this study. The procedure was to go into a crib where the corn had not been husked, take ears at random, sort them into 6 piles according to the following lengths of husk extension beyond the tip of the ear: 0, 0 to 1, 1 to 2, 2 to 3, 3 to 4, 4 to 5, and 5 to 6 inches. The proportionate number of ears with the different husk extensions was determined by counting the number of ears in all piles when the number of ears in any one pile had reached 100. Selections of ears was then continued until 100 ears of each husk-extension length had been obtained. The corn in each pile was then husked, and an average grade of earworm damage on an arbitrary 0 to 5 scale was obtained for each. The ears in each earworm grade in each husk-extension length were kept separate and counted, measured, and weighed, so that the average earworm grade of ears with husk extensions of 0, 0 to 1, 1 to 2, 2 to 3, 3 to 4, and 4 to 5 inches could be compared with all others with respect to earworm damage, husk

extension, weight, and ear length within a variety in each of the 10 cribs. These comparisons are shown in table 3, and the percentages of ears with each husk extension are shown in table 4 for 8 of the cribs of corn sampled. In table 4 each crib of Mosby represents a different strain.

In another study all the entries in the main 6-replicated corn-hybrid and -variety test at Stoneville, Miss., in 1945 were graded for earworm injury. The data from the entries placed in grade 2 for husk extension and tightness are given in table 5. As shown in this table, the earworm injury differed greatly among the varieties having approximately the same husk extension and tightness, and La. 1030 apparently exhibited a postitive tendency toward resistance that was not dependent on extreme length and tightness of husk.

Table 3.—Comparison of husk extension, earworm damage, weight per 100 ears, and length of ears in 10 corncribs near State College, Miss., 1945. (Data based on an average of 600 ears per crib.)

Husk Extension	Earworm Damage	Weight per 100 Ears	Length of Ears
Inches	*Grade*	*Pounds*	*Inches*
0[1]	3.54	37.9	8.1
0 to 1	2.92	38.4	8.3
1 to 2	2.74	35.2	8.1
2 to 3	2.77	32.4	7.7
3 to 4	2.75	29.5	7.3
4 to 5	2.82	24.2	6.6

[1] Tip of ear exposed.

Table 5.—Percentage of ears infested and grade of damage by the corn earworm in 10 different kinds of corn having husks of approximately the same average length and tightness (grade 2) at Stoneville, Miss., 1945.

Variety or Hybrid	Earworm Damage[1]	Infested Ears
	Grade	*Per Cent*
La. 1030	0.4	29
Miss. 5111	1.0	64
N. C. 4003	1.0	68
N. C. 4026	1.0	67
La. 468	1.2	72
N. C. 5001	1.3	70
Station Mosby	1.4	80
Sewell Jarvis	1.6	80
Jellicorse	1.8	88
Tenn. 10	2.5	96

[1] Difference necessary for significance of earworm-damage grade (5 per cent level) equals 0.26. Data from all varieties and hybrids included in the test were used in determining this difference.

Discussion.—In these studies, somewhat more earworm damage was done to ears having no husk protection, but a 2- or 3-inch husk extension afforded as much protection as did longer ones up to 5 or 6 inches (Table 3), and most of the ears of all varieties except one had husk extensions of 2 inches or more (Table 4). Earworm damage differed greatly among varieties and hybrids with approximately the same husk extension and tightness (Table 5). The positive tendency toward resistance in La. 1030 (Table 5), as indicated by its low earworm damage and percentage of infested ears, apparently did not depend on extreme length and tightness of husk.

Estimated tightness of husk in the inbred lines (Table 1) was correlated with total length of husk and with husk extension beyond the tips of the ears. In these lines the average length of the ears remained about uniform in all husk lengths. This condition is probably characteristic of the particular lines used in the tests. Within the variety and hybrid studies, however (Table 3), the length and weight

Table 4.—Percentages of ears with different husk extensions in each of 8 cribs of corn sampled, State College, Miss., 1945.

Husk Extension Inches	Percentages of Ears in Each Class by Variety or Strain							
	Funk Hybrid G714	Jarvis	Mosby 1	Mosby 2	Mosby 3	Mosby 4	Mosby 5	Mosby 6
0	20.2	10.5	10.4	26.0	13.2	10.2	1.9	0
0 to 1	35.5	29.1	19.5	21.1	18.7	21.5	12.2	37.0
1 to 2	23.8	30.0	33.6	21.4	29.2	36.5	32.2	30.7
2 to 3	9.6	15.6	19.1	15.4	18.1	19.3	31.5	23.3
3 to 4	6.0	10.2	9.1	8.6	10.5	8.0	12.2	4.8
4 to 5	5.0	4.5	8.4	7.6	11.0	4.4	10.0	4.4

of ears was, in general, inversely proportional to the husk extension.

From the data presented in this paper, it does not seem desirable to emphasize husk extension of more than 2 or 3 inches in breeding for protection from earworm injury. However, moderate husk extension and tightness seems desirable for protection from other corn insects, such as the rice weevil, as well as from birds, diseases, and weathering, in the development of satisfactory corn hybrids for the South.—

DDT to Control the Gulf Coast Tick

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During 1945 and 1946 the U.S. Bureau of Entomology and Plant Quarantine and the Florida Agricultural Experiment Station conducted cooperative studies on the control of certain ectoparasites of cattle, with special reference to the possible relation between these parasites and the transmission of anaplasmosis. In the course of this work experiments were conducted with DDT for control of the Gulf Coast tick, *Amblyomma maculatum* Koch.

The Gulf Coast tick is an important pest of livestock along the coast of the Gulf of Mexico and the South Atlantic seaboard. It is usually most prevalent within 100 to 150 miles of the coast. The lesions inflicted on the ears of livestock by the engorging female ticks are an important cause of screwworm infestations, and in most of Florida at least 80 per cent of all screwworm cases occurring in August and September are predisposed by the bites of this tick.

Since the Gulf Coast tick attaches almost entirely to the ears of animals, the usual treatment has been to swab the ears with various repellent or toxic materials. Pine tar oil was the accepted repellent for many years. Recently a smear known as stock 1037, containing 5 per cent of technical DDT in a non-drying adhesive base resin, has been developed by the Bureau of Entomology and Plant Quarantine (Rude 1946), and has proved to be more effective than pine tar oil.

The use of ear smears, however, has many objectionable features. Their application is a slow and laborious process, requiring that the animals be restrained in a chute. In treating wild cattle there is more or less danger of injury to the animals and to the stockman. For these reasons ear treatments are usually delayed in the Southeast until screwworm incidence has reached a critical stage.

In 1945, in connection with a horn fly test at St. Augustine, Florida, some significant observations were made which indicated that DDT sprays might be of use in controlling this tick. A large herd of Angus cattle was treated on July 27 with a spray containing 2.5 per cent of DDT. On the same day 150 of these animals were separated from the main herd and placed in a pasture that was supposed to be heavily infested with ticks. Fifty of the cattle were marked and their ears treated with an adhesive base smear containing 5 per cent of DDT. The remaining 100 animals were left untreated as checks. Both lots of animals were examined for ticks and tick lesions eight times between August 10 and October 12.

It was noticed from the first examination that the behavior of the ticks found on the animals was abnormal. An unusually large proportion of both sexes was found wandering aimlessly about on the animals, and very few were attached. On August 24 only 35 out of 71 ticks of both sexes found on both lots of animals were attached, and only a portion of these had started to engorge. Of 251 ticks of both sexes found on the untreated animals during the season, only 26 females started to engorge, and only 3 replete females were found during the season. Two replete females were observed on the ear-treated animals.

1946 TESTS.—In 1946 an attempt was made to verify the observations made the previous year and to compare on parallel lots of animals the effectiveness of a spray containing 2.3 per cent of DDT with that of the two best available ear smears. One of these smears was stock 1037. The other, designated as Savannah No. 5, was an

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experimental material containing 7.5 per cent of DDT which has been used with some success for the last two years. This smear represents an attempt to eliminate some of the disagreeable features of sticky semifluid resins and has the consistency of a heavy, slightly tacky cold cream. The smears were applied with the bare hands to both inner and outer surfaces of the animals' ears. The spray was made by mixing 2 pounds of 50 per cent water-dispersible DDT powder in 5 gallons of water, and was applied with an adjustable long-range orchard spray gun operated from a small power sprayer under a pressure of about 300 pounds per square inch. The animals were wet thoroughly on all parts of the body.

St. Augustine Test.—At St. Augustine a test was made on the ranch that was used in 1945. About 100 yearlings were separated from the main herd on August 13 and confined in a pasture by themselves. All cattle on the ranch had been sprayed by the owner in late June for the control of horn flies, with a DDT spray indicated by the foreman to be of about 0.3 per cent concentration.

The pretreatment tick infestation on the four lots of animals used in the test was fairly uniform (Table 1). The lot treated with Savannah No. 5 received an average of 1.6 ounces of smear per head, or about 3.6 grams of technical DDT. The lot treated with stock 1037 received 2.7 ounces each, or about 4 grams of DDT. The sprayed lot was treated twice, on August 13 and on September 5. The average application for the first spray was 2 pints, or about 21 grams, of DDT per head, and for the second application 2.4 pints, or about 26 grams of DDT. Both sprays were heavier than necessary, and there was considerable runoff. It is also doubtful whether the second spray materially affected the final results.

Table 1, which gives the results of this test, shows that six animals were lost from the treated lots during the test. This was due to the loss of identification marks. The check lot was unmarked and, therefore, was augmented by these six treated animals and by one that came in from outside. Although Savannah No. 5 shows a slightly poorer control than stock 1037 or the DDT spray, it is not believed that the difference is significant in a test of this character. However, the control on the sprayed lot was consistently equal to that on the two lots treated with ear smears.

Indiantown Test.—A test was made at Indiantown, Florida, on a herd of 227 crossbred Brahma-Angus cattle. The animals ranged from mature cows to suckling calves. These cattle were used in a test of ear smears in 1945 and at that time were heavily infested with ear ticks and screwworms. For some reason the 1946 tick population on these cattle was relatively light, and it is of interest to note that the owner had sprayed the cattle with DDT late in June 1946 for horn fly control. Since conditions surrounding the test indicated that not all of these cattle could be recovered at each examination, an arrangement somewhat different from that used at St. Augustine was adopted.

One lot of 46 animals received an ear treatment of 1.2 ounces of Savannah No. 5, or about 2.5 grams of DDT, per animal. The ears of another lot of 42 animals were treated with an average of 1.4 ounces of stock 1037 per head, or about 2 grams of

Table 1.—Relative effectiveness of two smears and a spray containing DDT against the Gulf Coast tick. St. Augustine, Florida.

TREATMENT	DATE OF OBSERVATION[1]	ANIMALS EXAMINED	TICKS	LESIONS	PER CENT CONTROL
Savannah No. 5	Aug. 13	25	70	19	
	22	25	10	0	
	Sept. 5	23	6	0	
	12	23	0	0	
	20	23	0	0	
	26	23	2	0	
	Oct. 4	24	1	0	
		Av.	0.14		68
Stock 1037	Aug. 13	25	63	15	
	22	25	3	0	
	Sept. 5	25	4	0	
	12	25	4	1	
	20	24	0	1	
	26	24	0	0	
	Oct. 4	24	1	0	
		Av.	0.08		82
DDT spray	Aug. 13	26[2]	71	10	
	22	25	6	0	
	Sept. 5	23	3	0	
	12	23	0	0	
	20	23	0	0	
	26	23	0	0	
	Oct. 4	22	2	0	
		Av.	0.08		82
Check (no treatment)	Aug. 13	30	70	20	
	22	31	49	14	
	Sept. 5	35	27	6	
	12	35	12	7	
	20	34	9	7	
	26	37	7	1	
	Oct. 4	37	2	0	
		Av.	0.44		0

[1] Figures for August 13 are pretreatment counts.
[2] 1 animal gained entrance from outside.

DDT. A third lot of 99 animals was sprayed once with 15 gallons of 2.3 per cent DDT spray, an average of 1.2 pints of the spray, or about 13 grams of DDT, per animal. The remaining 40 animals were untreated. Results were determined by examining the first 25 animals in each lot that came through the chute. It was impossible to see these cattle oftener than once every 2 weeks. The data are presented in table 2. On account of the infrequent examinations and the small number of ticks on the check animals, these results are less convincing than those from St. Augustine. They do, however, follow the same general pattern. At Indiantown the control of ticks in the sprayed lot was fully equal to that in either lot treated with ear smears. The pretreatment infestation at the beginning of the test was highest on the sprayed lot.

Table 2.—Relative effectiveness of two smears and a spray containing DDT against the Gulf Coast tick. Indiantown, Florida.

Treatment	Date of Observation[1]	Animals Examined	Ticks	Lesions	Per Cent Control
Savannah No. 5	Aug. 22	46	56	2	
	Sept. 3	25	1	0	
	18	28	4	1	
	Oct. 1	24	0	0	
		Av.	0.06		85
Stock 1037	Aug. 22	42	60	4	
	Sept. 3	25	1	1	
	18	25	1	1	
	Oct. 1	25	2	1	
		Av.	0.05		87
DDT spray	Aug. 22	38[2]	99	6	
	Sept. 3	25	3	0	
	18	26	0	3	
	Oct. 1	25	0	0	
		Av.	0.04		90
Check (no treatment)	Aug. 22				
	Sept. 3	25	16	3	
	18	25	14	1	
	Oct. 1	25	0	1	
		Av.	0.39		0

[1] Figures for August 22 are pretreatment counts.
[2] 99 animals sprayed.

MISCELLANEOUS OBSERVATIONS.—An informal ranch test was made on a large herd near Chuluota, Florida. A herd of 500 cattle that grazed in heavy hammock pasture, where tick-induced screwworm incidence has been a serious problem, were penned and sprayed on September 4. There were 19 active screwworm cases on the animals. Thirty-eight head, individually checked, had 42 ticks and 11 susceptible lesions. These animals were marked and released without further treatment. All active screwworm cases were treated with smear 62. The remaining 462 were sprayed with an average of 1 pint of 2.3 per cent DDT spray per animal, or about 11 grams of DDT. These animals were checked for screwworms by riders about two or three times a week. On September 30 only 1 active screwworm case had developed in the herd subsequent to treatment. The owner was so impressed by the results that he penned and sprayed the remainder of his cattle about the middle of September.

CONCLUSIONS.—From the results of two years' experiments it is concluded that a full-coverage DDT spray will control Gulf Coast ticks as effectively as the best ear smears so far developed. Since the tests were begun late in the season, the number of applications necessary for a full season's protection in the Southeast has not been determined. It seems unlikely, however, that the number would be more than for ear smears. Since the sprays applied have involved saturation coverage with high concentrations, the minimum effective dose has not been determined. However, a lower concentration of DDT than those used might be fully effective. The simplicity of this method, as well as the fact that it will control other blood-sucking parasites of cattle, such as mosquitoes, horn flies, stable flies, and lice, suggests that DDT sprays against Gulf Coast ticks will come into general use in the near future.

LITERATURE CITED

Rude, C. S. 1946. A new remedy for the control of the Gulf Coast tick. U. S. Bur. Ent. and Plant Quar. E-686.

Manual Infestation of Dent Corn to Study Resistance to European Corn Borer

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In order to determine the resistance or susceptibility of different strains of corn to survival of the European corn borer, *Pyrausta nubilalis* (Hbn.), or the effects of different numbers of borers per plant on yield and stalk breakage, heavier infestations than those provided by nature are usually required. These can be produced by obtaining egg masses in quantity from moths reared in the laboratory, by a modification of the method described by Patch & Pierce (1933), and placing them on the plants by hand. By this method small disks of waxed paper each bearing an egg mass are pinned on the plants just before the eggs hatch.

For the most efficient use of egg masses placed on the plants artificially, it is necessary to know the number to use and the conditions under which to use them to obtain different levels of infestation. The experiments described in this paper show that the number required varies with the growth stage of the plants at the time of infestation and with the fertility of the soil in which the plants are growing.

BORERS SURVIVING FROM DIFFERENT NUMBERS OF EGG MASSES HATCHING AT DIFFERENT TIMES PRIOR TO SILKING.—Three field-plot experiments were conducted to determine the numbers of borers that survived when 3, 6, and 12 egg masses per plant were put on the plants at different stages in the growth of the corn from 40 days prior to silking up to and including the silking stage.

An experiment using Iowa hybrid No. 939 was conducted near Toledo, Ohio, in 1940 on fourfold-replicated plots planted on May 8, 17, and 25, and June 8 in a modified Latin-square arrangement. The plots contained 4 hills 42 inches apart each way. Each hill was thinned to 4 plants, and storms later reduced the total number of perfect plants of each treatment from 64 to an average of 58. The plots were separated by 2 vacant rows on each side to prevent wind-blown migration of young larvae from one plot to another. All the plants in each plot that were manually infested received additional egg masses on July 5 at the peak of natural oviposition, from 20 to 31 days prior to silking depending on the planting. At that time the plants appeared especially thrifty, the successive plantings measuring 59, 55, 48, and 36 inches to the tips of the leaves extended upward. The egg masses averaged about 20 eggs each. Each plant was tagged with the date of silking, and all plants were dissected in the latter part of August to determine the number of mature borers per plant. The percentage increases in the borer populations obtained by augmenting with 6 and 12 egg masses per plant over the populations obtained with 3 egg masses are given in table 1.

The method used in 1940 was modified in 1941 and 1942 by making plantings on three instead of four dates and by infesting with eggs early, at midseason, and late instead of at one time. The plots were planted with threefold instead of four fold replication and thinned to three instead of four plants per hill. The effects on survival of larvae from eggs hatching when the plants were in nine growth stages were thus available for study.

In 1941 plantings made on May 6, May 20, and June 2 were infested on July 4 ,13, and 21. This procedure resulted in a difference of 35 days from egg hatching to corn silking between the least mature and the most mature corn at time of artificial infestation. The most mature corn was showing fresh silks at that time. The natural infestation averaged 0.9, 0.8, and 0.3 borer per plant on the respective plantings.

In 1942 plantings made May 2, 18, and 28 were infested on June 18, July 10, and July 18, when the difference in maturity between the most mature corn, which was

[1] Acknowledgment is made to G. W. Still and Clarence Crooks, who assisted with the experiments on different levels of soil fertility; to G. W. Conrey and J. S. Cutler of the Ohio Agricultural Experiment Station, who selected the soil type and fertilizers, provided seed of the Clarage variety, and rendered advice; and to R. T. Everly, who provided laboratory-produced egg masses and assisted in planning the experiments and tabulating and analyzing the data. The work reported herein for 1942 was conducted at Lafayette, Ind., in cooperation with the Purdue Agricultural Experiment Station and the U. S. Bureau of Plant Industry, Soils, and Agricultural Engineering.

Table 1.—Increases in European corn borer populations obtained by augmenting natural infestation in dent corn with 3, 6, and 12 egg masses. Toledo, Ohio, 1940–41, and Lafayette, Ind., 1942.

Days from Egg Hatching to Corn Silking	Number of Borers per Plant[1]		Per Cent Increase Over 3 Egg Masses	
	Natural Infestation	3 Egg Masses Added	6 Masses Added	12 Masses Added
1940				
20	2.7	6.5	12	29
22	2.3	5.9	25	49
25	2.0	7.6	1	18
31	1.7	6.0	40	50
Mean	2.18	6.50	19.5	36.5
1941				
0	0.9	6.7	36	121
6	.8	4.2	0	76
7	.9	3.2	34	78
14	.8	2.7	33	59
16	.9	2.9	31	48
18	.3	2.5	72	84
24	.8	1.4	36	86
25	.3	0.9	44	144
35	.3	1.6	50	106
Mean	.67	2.90	37.3	89.1
1942				
0	1.5	10.3	19	85
4	1.0	6.2	89	140
8	1.5	6.9	23	87
9	.3	7.5	16	51
12	1.0	4.7	53	53
16	.3	2.6	85	73
29	1.5	3.4	12	41
35	1.0	3.1	−26	29
40	.3	2.2	18	45
Mean	0.93	5.21	32.1	67.1

[1] Averages based on samples of 58 plants in 1940, 36 in 1941 and 18 in 1942.

showing fresh silks at time of infestation, and the least mature corn was 40 days. The natural infestation averaged 1.5, 1.0 and 0.3 borers per plant on the respective plantings.

The percentage increase in the number of borers obtained by augmenting with 6 rather than with 3 egg masses per plant was about as much in 1941 as in 1942 and about twice as much as in 1940 (table 1). With allowance for variations due to experimental error, the data in table 1 indicate also that these increases apparently apply as well to corn near the silking stage as to corn silking after the eggs hatched.

The percentage increase in the number of borers obtained by augmenting with 12 rather than with 3 eggs masses per plant was somewhat greater in 1941 than in 1942. The increase in 1941 appeared to apply as well to the corn that was least mature when the eggs hatched (24 to 35 days before silking) as to corn that was near the silking stage. In 1942, however, the conditions in the corn that was near the silking stage when the eggs hatched apparently favored a greater increase than those in the corn that was less mature at that time. When the interval between egg hatching and corn silking was 8 days or less, the application of 12 rather than 3 egg masses per plant increased the number of borers by an average of 104 per cent; when the interval was from 9 to 16 days, the increase averaged 59 per cent; and when the interval was from 29 to 40 days, the increase averaged 38 per cent. The 9 pairs of values in table 1 were used to calculate the regression of percentage increase on the interval between hatching and silking. The chances of the lowered increases not being due to differences in growth stages of the plants at the time of artificial infestation are only 4 in 1000.

EFFECT OF PUTTING EGGS ON PLANTS AT ONE TIME AS COMPARED WITH PUTTING THEM ON AT THREE TIMES.—The method used in 1940 was further modified in 1941 and 1942 by including in the experiments series of plots in which each plant received a third of its complement of eggs early in, a third in the middle of, and a third late in the period when eggs were available in June and July. From the data obtained the effect on borer survival of putting eggs on at three times as compared with putting them all on at any one time was considered. The effect of weather was obviated by comparing the number of borers from plants infested at three times with the average number from the three plots whose plants received their full complement of eggs early, at midseason, and late. The plants receiving each third of their complement at different times were infested on the same days as the plants receiving their full complement early, at midseason, or late. The data are given in table 2.

Comparison of the mean number of borers resulting from the early, midseason, and late single applications of eggs with the number resulting from applications in three successive comple-

Table 2.—Effect of time of planting, time of putting eggs on plants, and of infesting plants all at one time compared with infesting them at three different times, Toledo, Ohio, 1941, and Lafayette, Ind., 1942.

Time of Planting	Time of Putting Eggs on Plants	Number[1] of Borers per Plant from Indicated Number of Egg Masses		
		3	6	12
1941				
Early	All early	2.9	3.8	4.3
	All at midseason	3.2	4.3	5.7
	All late	6.7	9.1	14.8
	Mean	4.3	5.7	8.3
	At 3 times	4.1	5.8	8.1
Midseason	All early	1.4	1.9	2.6
	All at midseason	2.6	3.6	4.3
	All late	4.2	4.2	7.4
	Mean	2.7	3.2	4.8
	At 3 times	2.6	3.2	5.6
Late	All early	1.6	2.4	3.3
	All at midseason	0.9	1.3	2.2
	All late	2.4	4.3	4.6
	Mean	1.6	2.7	3.4
	At 3 times	2.1	3.0	3.6
1942				
Early	All early	3.3	3.7	4.7
	All at midseason	6.9	8.5	12.8
	All late	10.2	12.2	19.1
	Mean	6.8	8.1	12.2
	At 3 times	7.9	10.8	13.7
Midseason	All early	3.1	2.3	4.0
	All at midseason	4.7	7.2	7.2
	All late	6.2	11.7	14.9
	Mean	4.7	7.1	8.7
	At 3 times	6.1	7.9	9.8
Late	All early	2.2	2.6	3.2
	All at midseason	2.6	4.8	4.5
	All late	7.5	8.7	11.3
	Mean	4.1	5.4	6.3
	At 3 times	3.4	5.3	7.9

[1] Based on 36 plants in 1941 and 18 in 1942.

ments shows that in 1941 the difference was small in each case. In 1942, however, infesting each plant with egg masses at three different times instead of all at one time increased the number of borers per plant 20 per cent on the early planting and 16.2 per cent on the midseason planting. On the late planting the average increase was small.

EFFECT OF DIFFERENT LEVELS OF SOIL FERTILITY ON LARVAL SURVIVAL.—In addition to the effect of plant maturity and of time of placement of eggs, the effect of different levels of soil fertility on rate of larval survival was studied. Experiments were conducted for four consecutive years on a very fine sandy-loam soil near Sandusky, Ohio, each year on different ground. Each year one-third of the area to be planted received no fertilizer; one-third received 1.5 tons of dry shredded cattle manure and 150 pounds of superphosphate per acre, disked in before planting, and in addition 150 pounds of a 4-12-4 fertilizer was placed in the hills at planting time; and the other third received double the amounts of these fertilizers. Each year all plots were planted on the same date, in early May. At the peak of natural oviposition each year all plots that were infested by hand received the eggs on the same date.

The number of borers per plant resulting from given numbers of egg masses placed on the plants by hand were obtained from plots of 5 by 6 hills with 5 replications in 1929, of 1 by 12 hills with 15 replications in 1930, of 1 by 12 hills with 12 replications in 1931, and of 4 by 6 hills with 5 replications in 1932. One series of plots was subject to natural infestation only, one series received in addition 1 egg mass per plant by hand, one series received either 2 or 3 masses per plant, and one series received 3 or 5 according to the year. The reliability of the numbers of borers resulting from the eggs placed on the plants by hand was enhanced by the fact that each year the numbers of borers present in the naturally infested plots were relatively small. The yields of grain in the absence of borers were estimated from the calculated regression of yield per acre on number of borers per plant based on data from identically fertilized plots that respectively contained different populations of borers. The data are given in table 3.

The mean values in table 3 indicate that 4.00 borers per plant were gained from the additional eggs placed on the plants receiving no fertilizer, that 5.22 borers were gained where the lower application of fertilizer was applied, and that 6.07 borers were gained where the higher application was applied. The gains of 5.22 and 6.07 borers per plant are 31 and 52 per cent greater, respectively, than for the plants receiving no fertilizer, and these greater gains resulted from increases in the rate of borer survival.

The natural infestation was 39 per cent greater with the lower application of fertilizer than with no fertilizer and 65 per cent greater with the higher application. These percentages are somewhat more than the corresponding gains of 31 and 52 per cent obtained with the augmented infestations. Probably the 39 and 65 per cent increases of the natural infestations were due to additional numbers

of egg masses laid on the taller corn (Patch 1942) in the plots that were fertilized as well as to increased rates of borer survival on the fertilized plots.

An estimate can be made of the portions of the increases in the rate of larval survival in the fertilized plots due, respectively, to earlier maturity and to other utable to nutritional, morphological, or other changes in the plants favoring the survival of larvae.

DISCUSSION.—A study of the data in table 1 indicates that the addition of 6 and 12 instead of 3 egg masses per plant gave increases from year to year in the borer population that were variable but not

Table 3.—Effect of different quantities of fertilizer on survival of larvae of the European corn borer in dent corn planted on a very fine sandy loam, Sandusky, Ohio, 1929–32.

YEAR	HEIGHT[1] (IN INCHES) OF CORN WHEN EGGS HATCHED	DATE OF SILKING	NUMBER OF BORERS PER PLANT						BUSHELS OF GRAIN PER ACRE
			Natural Infestation	Natural Infestation Augmented by Indicated Number of Egg Masses					
				1	2	3	5	Mean	
No fertilizer used									
1929	60	August 6	1.1	1.6	2.5	3.0	—	2.4	31.3
1930	67	July 29	0.5	2.2	—	3.0	4.6	3.3	50.3
1931	—	24	3.4	7.4	10.7	16.4	—	11.5	62.2
1932	43	28	1.7	3.5	—	5.8	7.2	5.5	83.9
Mean	56.7	July 30	1.68	—	—	—	—	5.68	56.9
Single application of fertilizer									
1929	66	August 8	1.0	2.8	2.9	4.4	—	3.4	30.1
1930	78	July 27	1.3	2.7	—	4.5	6.0	4.4	53.5
1931	—	22	3.8	10.9	13.6	19.8	—	14.8	65.6
1932	55	25	3.2	4.9	—	8.7	9.3	7.6	79.3
Mean	66.3	July 28	2.33	—	—	—	—	7.55	57.1
Double application of fertilizer									
1929	72	August 3	1.6	3.5	4.3	8.6	—	5.5	34.5
1930	85	July 26	2.0	3.2	—	5.7	7.9	5.6	51.8
1931	—	21	4.4	10.1	16.2	21.8	—	16.0	71.9
1932	59	24	3.1	5.7	—	8.9	10.3	8.3	85.0
Mean	72.0	July 26	2.78	—	—	—	—	8.85	60.8

[1] From ground to tips of extended leaves.

causes. In experiments by Patch and Everly (1945) borer populations were found to be 4.3 per cent greater for each day earlier in silking at all levels of borer populations. With the 2 and 4 days earlier silking of the plants receiving fertilizer (Table 3), and the increase of 4.00 borers per plant in the plots receiving no fertilizer, gains of 4.34 and 4.69 borers per plant would be expected from plants receiving the lighter and heavier applications of fertilizer. Instead, gains of 5.22 and 6.07 borers were obtained. Hence earlier maturity of the plants would account for increases of 8.5 and 17.3 per cent in numbers of borers, and increases of 22.0 and 34.5 per cent would be attrib-

proportional. In 1940, when the eggs hatched from 20 to 31, or an average of 24.5, days prior to silking, three additional egg masses per plant resulted in 6.50 borers per plant. Doubling the additional eggs increased the number of borers by only 19.5 per cent, and quadrupling them increased the number by 36.5 per cent. In 1942, when the eggs hatched from 16 to 35, or an average of 26.7, days prior to silking, three additional egg masses resulted in 3.03 borers per plant. Doubling the additional eggs increased the number of borers by 23.7 per cent, and quadrupling them increased the number by 47.7 per cent. In 1941, when the eggs hatched from 18 to 35, or

an average of 25.5, days prior to silking, the addition of three egg masses resulted in 1.60 borers per plant. Doubling the additional eggs increased the number of borers by 50.5 per cent, and quadrupling them increased the number by 105 per cent. These percentages applied to the number of borers obtained by augmenting with three egg masses give the average numbers of borers per plant obtained by augmenting with additional eggs.

A study of the data from all three fertility levels in table 3 indicates that the addition of three and five egg masses instead of one egg mass per plant increased the borer population 63 and 128 per cent, respectively, in 1930, and 66 and 90 per cent in 1932.

These data bring out a point observed in other experiments as well as these. When the growing conditions of the corn are favorable to larval establishment, considerably more borers may result from the addition of three egg masses per plant than from more than three masses when conditions are unfavorable. In fact, in an experiment conducted in 1945 on several plantings of corn declared to be exceptionally thrifty, no material increase in the number of borers was obtained by augmenting with 12 and 24 egg masses per plant. An average to 1.03 borers per plant was found where natural oviposition amounted to 1.7 egg masses per plant, and 1.10 borers where an average of 18 additional masses were put on each plant from June 30 to July 2. Rainfall totaled 5.86 inches from April 27 to May 27, and 7.74 inches for June. The corn plants growing under these conditions possibly did not provide the nutriments required by the larvae for establishment.

A study of the data in table 1 shows also that plant maturity at time of infestation has a profound effect on the rate of larval survival. Natural oviposition augmented with three egg masses per plant when the plants showed fresh silks resulted in 5.1 times as many borers in 1941, and in 3.6 times as many in 1942, as when the eggs were placed on the plants from 24 to 40 days prior to silking. In fact, plant maturity had so much effect on the rate of larval survival that adding 12 egg masses per plant 6 or 7 days prior to silking in 1941, and 4 to 8 days prior to silking in 1942, resulted in only about as many borers as adding three egg masses when the plants showed fresh silks.

The gain in borer population by infesting each plant with additional eggs at three different times during the season was not much more than the gain by placing all the egg masses on each plant at one time.

The experiment using different levels of soil fertility showed important increases in the rates of larval survival on the fertilized soil over those on the unfertilized soil. The experiment showed that additional egg masses may increase the borer population as much as 52 per cent when corn grows on fertile, well-drained soil.—6-12-47.

LITERATURE CITED

Patch, L. H., and L. L. Peirce. 1933. Laboratory production of clusters of European corn borer eggs for use in hand infestation of corn. JOUR. ECON. ENT. 26(1): 196–204.

Patch, L. H. 1942. Height of corn as a factor in egg laying by the European corn borer moth in the one generation area. Jour. Agr. Res. 64(9): 503–15.

Patch, L. H., and Ray T. Everly. 1945. Resistance of dent corn inbred lines to survival of first-generation European corn borer larvae. U. S. Dept. Agr. Tech. Bul. 893.

DR. M. D. LEONARD

Dr. M. D. Leonard has recently joined the staff of Julius Hyman & Company, Denver, Colorado and will participate in the Technical Sales and Development activities of the Eastern Sales Office of the company.

Dr. Leonard, during the war, was Chief of the Insecticide Unit of the O.P.A. and later was associated with the Bureau of Entomology and Plant Quarantine in Washington, D. C. Mr. Leonard's Washington address will remain the same as it has been in recent years.

Benzene Hexachloride to Control Cattle Lice

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In view of the striking insecticidal properties reported for hexachlorocyclohexane, or benzene hexachloride as it is now called officially, when used on a wide range of insect species, it seemed that this material might well prove to be superior to existing insecticides for the control of cattle lice. Standard treatment methods with rotenone and sulfur provide excellent control of the motile forms of cattle lice when used as a dip, but there is no ovicidal action nor is there sufficient residual action with this method to kill the nymphs as they hatch. Therefore two or three treatments have been necessary to obtain efficient control of the parasites. This means that the greatest cost of treating cattle for lice has been for labor and for the weight loss incident to driving and handling the cattle more than once. Any new insecticide against cattle lice, to qualify as an improvement, should thus have the power to control louse infestation efficiently with one treatment.

Several workers have reported promising results with DDT against cattle lice. Simms (1946) indicates that 0.3 and 0.6 per cent emulsions of DDT eradicated the short nosed sucking louse and the biting louse, and greatly reduced the population of the long nosed sucking louse when applied as a single dip. He also reported that complete control of sucking lice was obtained for 8 weeks with an emulsion spray of 0.25 per cent benzene hexachloride (30 per cent gamma isomer content, thus 0.075 percent gamma in the spray).

Fairly satisfactory control of *Haematopinus eurysternus* and *Bovicola bovis* using a 10 per cent DDT dust with pyrophyllite, was reported by Munro & Knapp (1945).

Wells & Barrett (1946) report a 100 per cent ovicidal action to eggs of *Haematopinus eurysternus* with benzene hexachloride aqueous suspension containing 0.1 per cent of the gamma isomer.

TECHNIQUES AND MATERIALS.—Preliminary tests were conducted on the viable eggs of *Haematopinus eurysternus* (Nitzsch) by spraying large numbers of eggs contained in clumps of hair with various concentrations of an aqueous benzene hexachloride suspension. A small hand sprayer producing a fine droplet spray was used. For comparative purposes eggs were treated similarly with DDT suspensions and with water. Following treatment the eggs were cultured at 35° C. and approximately 84 per cent relative humidity.

The commercial benzene hexachloride mixture used consisted of 50 per cent benzene hexachloride 0.75 per cent sodium lauryl sulfate, and the remainder a mixture of inert diluents. In discussing the results obtained reference is made to the actual amount of benzene hexachloride used, rather than to the amount of the mixture involved. The alpha isomer of the benzene hexachloride was 65 to 75 per cent, beta 6 to 8 per cent, gamma approximately 12 per cent and delta 6 to 7 per cent.

A preliminary field test was made on cattle using a spray composed of 8 pounds of 50 per cent wettable benzene hexachloride to 150 gallons of water, providing a concentration of 0.32 per cent of benzene hexachloride. A portable sprayer was used providing 300 pounds pressure. The spray hoses were supplied with single head disk nozzles. The experimental animals consisted of one bull heavily infested with *Haematopinus eurysternus* and 77 range heifers lightly infested with *Linognathus vituli* (Linn) and a few ticks, *Dermacentor occidentalis* Marx. All animals were thoroughly drenched. The heifers were examined 3 days later and the bull was examined 3 and 41 days after treatment for evidence of infestation.

All other field tests were concerned with dips prepared from 50 per cent wettable benzene hexachloride powder in concentrations ranging from 0.15 to 0.5 per cent benzene hexachloride. Standard dip tanks were used and the head of each animal was thoroughly submerged as it swam through the vat. Lice and eggs were collected just before and 30 minutes to 2 hours after treatment from representative animals among the first and last of each series tested. Unless otherwise indicated the number of eggs in each sample was several hundred. In addition samples

[1] The author acknowledges the cooperation of Mr. Glenn Rouse of Niagara Sprayer and Chemical Division of the Food Machinery Corporation.

were collected at later intervals as reported in the section of results. All samples were cultured as described above. Infestations treated include *Haematopinus eurysternus*, *Linognathus vituli* and *Bovicola bovis* Linn. A fourth species. *Slenopotes capillatus* Enderlein, occurs in California, but was not found until too late in the season to include in the current experiments.

RESULTS: LABORATORY TESTS ON EGGS OF *Haemotopinus eurysternus*.—Egg samples thoroughly drenched with water suspensions of benzene hexachloride at strengths of 0.06, 0.125, 0.25 and 0.5 per cent failed to hatch in a 9-day period of culturing, although a few live embryos were dissected on the 9th day following treatment from the samples sprayed with 0.06 and 0.5 per cent benzene hexachloride. Within 9 days following a light spray of benzene hexachloride at concentrations of 0.10 and 0.125 per cent many eggs hatched, producing active larvae. In tests using an aqueous suspension of DDT at strengths of 0.125 and 0.5 per cent. thorough drenching failed to prevent the hatch of many eggs within 9 days. Control samples drenched with water likewise showed many eggs hatching.

FIELD SPRAY TEST ON CATTLE.—Seventy-seven range heifers and one bull were sprayed November 9, 1946 with 0.32 per cent benzene hexachloride aqueous suspension. Motile forms of *Haematopinus eurysternus* and *Linognathus vituli* were all dead on animals examined 3 days following treatment. Although it was impossible to check the heifers more than once after the 3 day period, examination of the bull 41 days after spraying showed that eradication of its former pure infestation of *H. eurysternus* was complete. It should be noted that both live and dead ticks, *Dermacentor occidentalis*, were found on the treated heifers 3 days following treatment, however, since the original tick infestation was light no attempt was made to obtain further data on tick control at the time.

Three range heifers with moderately heavy infestations of *Haematopinus eurysternus* were dipped December 24, 1946 in a 0.3 per cent suspension of benzene hexachloride. No ill effects were evident in the treated animals at any time. Egg samples taken before treatment hatched satisfactorily in the laboratory. Eggs taken 30 minutes after treatment of the animals failed to hatch, although in samples taken 3 days following treatment many eggs hatched when cultured in the laboratory.

Three days after dipping the heifers were pastured with 3 cows having moderate infestations of *Linognathus vituli* and *Bovicola bovis*, in order to determine if they could pick up the infestation. When examined 21 days following treatment there were no live *Haematopinus eurysternus* or viable eggs on the heifers, but 1 live *Linognathus vituli* adult and 2 dead *Bovicola bovis* adults were found during a careful examination.

On January 15, 1946, 292 yearling range cattle were dipped in a water suspension of 0.5 per cent benzene hexachloride. The animals had a light to moderate infestation of *Haematopinus eurysternus*, *Linognathus vituli* and *Bovicola bovis*. All lice were dead on animals checked 5 days and 3 weeks after treatment. The data on effects of the dipping on the eggs are tabulated as follows: From animal No. 1 a pre-treatment sample of 100 eggs resulted in a 95 per cent hatch within 19 days. A 1 hour post-treatment sample of 100 eggs gave a 31 per cent hatch, and a 5 day post-treatment sample of 44 eggs showed a 41 per cent hatch. From animal No. 2 a pre-treatment sample of 100 eggs resulted in an 85 per cent hatch while a 1 hour post-treatment sample of 30 eggs entirely failed to hatch. At 5 days post-treatment only 3 eggs could be found on animal No. 2 which were not obviously dead or hatched. Of these 3 eggs, 2 hatched when cultured in the laboratory.

The animals subjected to intensive examination were selected from among the first and last respectively of the cattle as they were being treated. The eggs of *Bovicola bovis* were not included in the data record due to their scarcity. All unhatched eggs found 3 weeks after dipping proved to be dead upon dissection. A few live and dead ticks were found at this time, some attached and feeding. They were *Ixodes pacificus* and *Dermacentor occidentalis*.

In connection with this experiment the following observations were made on *Otobius megnini*, the spinose ear tick. Three nymphs collected before treatment from the ear of a heifer lived over 8 days

in the laboratory. Five nymphs collected 1 hour after treatment from the same animal, died within 5 days in the laboratory.

On February 22, 1947, 2 heifers were dipped in the same dip that had been prepared and used on January 15th. The animals were heavily infested with *Haematopinus eurysternus* and with spinose ear ticks. When examined 3 days later no live lice were found. Of 100 eggs collected at this time and cultured in the laboratory, 12 per cent hatched within 18 days of the treatment. Numerous live and active spinose ear ticks were also collected 3 days after treatment and cultured in the laboratory where they survived for over 5 days.

On January 23, 1947 the following numbers of cattle were dipped in water suspensions of benzene hexachloride: 12 in 0.15 per cent benzene hexachloride, 50 in 0.3 per cent benzene hexachloride and 150 in 0.5 per cent benzene hexachloride. All animals were moderately heavily infested with *Bovicola bovis*. At each concentration pre- and post-treatment (1.5 to 2 hours) samples of 100 eggs each were taken from a representative animal. The three pre-treatment samples showed a uniformly high viability of 96, 99 and 98 per cent hatch when cultured in the laboratory. None of the post-treatment samples of eggs hatched under identical culture conditions. Examinations of the cattle 12 days after dipping at the 3 different concentrations of benzene hexachloride revealed only dead lice and eggs. Non viability of the unhatched eggs at this time was determined by dissection of representative samples (30–50 eggs).

DISCUSSION.—The results of laboratory tests with eggs of *Haematopinus eurysternus* indicated a high degree of ovicidal activity of benzene hexachloride at concentrations ranging from 0.06 to 0.5 per cent concentration of a mixture of isomers containing approximately 12 per cent of the gamma isomer, where little or no ovicidal activity was demonstrated by DDT suspensions at concentrations of 0.125 and 0.5 per cent.

Interpretation of the laboratory tests must be modified somewhat in the basis of the results obtained in the field. An overall statement of the results of the field tests may be made to the effect that complete eradication of louse infestation with 1 treatment was obtained in every field test where animals were dipped in 0.15 to 0.5 per cent of a suspension of benzene hexachloride. *Bovicola bovis* was the only species tested at a 0.15 per cent concentration, but the statement applies also to *Haematopinus eurysternus* and *Linognathus vituli* infestations at the range of 0.3 to 0.5 per cent benzene hexachloride.

The toxicity of benzene hexachloride to lice was manifested in 3 ways: 1. By complete kill of all motile stages of lice. 2. By a rather high ovicidal action against *Haematopinus eurysternus* and *Linognathus vituli* and an apparently complete ovicidal action against *Bovicola bovis*. 3. By a lethal action against all emerging nymphs. The third factor may be actually a manifestation of delayed ovicidal action or it may be a residual action of the toxicant on the hide. If it is due to the latter there is a possibility that heavy rains shortly after treatment might reduce the residual action of the benzene hexachloride to such an extent that complete control of emerging larvae would not be obtained.

In discussing the results of the field tests one factor of experimental error should be considered. In several instances eggs collected and cultured within 1 hour after treatment showed a 100 per cent mortality, while eggs collected from the same animals several days following treatment demonstrated an appreciable viability. This is probably due to the fact that there was greater aeration of the eggs on the animals than of those cultured, and thus any fumigant action of the benzene hexachloride was intensified under laboratory conditions.

Evidence that prepared dip does not lose its toxicity to lice rapidly is indicated by that fact that complete kill of all motile stages of *Haematopinus eurysternus* and a high ovicidal activity were demonstrated on cattle treated in a dip prepared and used 38 days prior to the test.

As pointed out in a previous report (Furman, 1947) tests completed to date have not ruled out the possibility of contamination of milk and meat in the period immediately following dipping or spraying cattle with aqueous suspensions of benzene hexachloride. However, a generous safety factor for cattle was demonstrated to exist when a commercial mixture of the type described in this paper was used.

It is recommended that dips of hexachlorocyclohexane be used for the control of cattle lice on a supervised demonstra-

tional basis until the accumulation of further field data makes possible either an unreserved or limited recommendation for general use.

SUMMARY.—Louse infestations of *Haematopinus eurysternus* and *Linognathus vituli* were eradicated by 1 dip in a 0.3 per cent suspension of benzene hexachloride (equivalent to approximately 0.036 per cent gamma isomer). *Bovicola bovis* infestations were eliminated by a single dip in 0.15 per cent benzene hexachloride. The toxicity of benzene hexachloride to cattle lice was manifestested in 3 ways: 1. By complete kill of all motile stages. 2. By a rather high ovicidal action. 3. By failure of any emerging nymphs to survive on the treated animal.

Evidence was presented that a prepared suspension of benzene hexachloride retained its effectiveness in a field vat for at least 38 days.—4-14-47.

LITERATURE CITED

Furman, D. P. 1947. Toxicity of benzene hexachloride to mammals. JOUR. ECON. ENT. 40(4): 518–21.

Munro, J. A., and R. Knapp. 1945. Effect of DDT on cattle lice. North Dakota Expt. Sta. Bimonthly Bul. 7(4): 21.

Simms, B. T. 1946. U.S.D.A. Rept. Chief, Bur. Animal Ind. p. 48.

Wells, R. W., and W. L. Barrett, Jr. 1946. Benzene hexachloride as an ovicide for the short-nosed ox louse. JOUR. ECON. ENT. 39(6): 816.

The Fog Aerosol Machine to Control Vegetable Insects

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In recent years great advancements have been made in the formulation of new insecticides as can be seen by the numerous papers on DDT and other insecticides. However, very little progress has been made on new methods of applying these insecticides to insect pests of field and vegetable crops. Recently, some preliminary work has shown that the aerosol method of insecticidal application is very effective. Ditman *et al.* (1946) obtained very excellent control of pea aphids with DDT in the aerosol form. Bronson & Smith (1946) also controlled pea aphids with the use of DDT as an aerosol. Using DDT, Glasgow (1946) reports excellent control of pea aphids up to a distance of 50 feet from a thermal fog generator. Glasgow & Collins (1947) report excellent control of houseflies and punkies with this machine. Using the same machine, Collins & Glasgow (1946) practically eliminated clothes moths in a wool storage warehouse with DDT.

In the late fall of 1946 a thermal aerosol fog generator[1] was made available for a limited time for experimental use against truck crop insects in the Lower Rio Grande Valley.

The purpose of the preliminary experiments presented in this paper was threefold: (1) to determine if insecticides applied as aerosols would give commercial control of various insects in the field; (2) to determine the distances from the outlet of the machine that the fog drift would effectively control insects; (3) and to determine some of the factors limiting the effectiveness of this method of application.

MATERIALS AND METHODS.—Water or common kerosene was used as the aerosol media for the insecticides in these experiments. The insecticides used are shown in the various tables. The aerosol machine was mounted on a truck, and this truck was driven through the field at the same rate of speed used in applying sprays to row crops.

In the first experiment *Diabrotica balteata Lec.* beetles were collected from tomato plants and then placed in small wire screen cages. These cages were placed on the ground near tomato plants at such locations that they were 20, 40 and 60 feet away from the aerosol machine as it was driven through the field. The insecticide consisted of a mixture of 5 per cent DDT and 0.03 per cent pyrethrins in kerosene. The effectiveness of the large, medium and small aerosol particles was tested. After the insecticide treatment, the cucumber beetles were brought into the laboratory and observed for 48 hours.

The second experiment was conducted

[1] Todd Insecticidal Fog Applicator, manufactured by the Todd Shipbuilding Corp.

Table 1.—The mortality of banded cucumber beetles, caged at various distances from the aerosol outlet, 48 hours after treatment with a mixture of 5 per cent DDT and 0.03 per cent pyrethrins in a kerosene aerosol of different particle sizes.

Aerosol Particle Size (Microns)	Distance from Aerosol Outlet					
	20 feet		40 feet		60 feet	
	Beetles	Mortality	Beetles	Mortality	Beetles	Mortality
30	46	94%	4	100%	29	38%
20	35	83	18	0	—	—
10	27	0	—	—	—	—

in a cabbage field. Because of the light worm infestation, worms were collected and placed in wire screen cages. These cages, each containing 10 cabbage loopers, *Trichoplusia ni Hbn.*, were placed on the ground near cabbage plants at such locations that they were 25 and 50 feet away from the machine as it was driven through the field. The insecticide used consisted of 7.5 pounds of 50 per cent wettable DDT in 10 gallons of water. These worms were treated with the large and medium DDT aerosol particles. After treatments, the cabbage loopers were taken into the laboratory and observed for 48 hours.

The large aerosol particles were used in all the remaining experiments. The third experiment consisted of fogging a section of an eggplant field in order to determine at what distance from the machine the aerosol fog would effectively control eggplant insects. The aerosol treatment consisted of a mixture of 2 ounces of nicotine, 2 ounces of 20 per cent pyrethrum extract and 7.5 pounds of 50 per cent wettable DDT in 10 gallons of kerosene. Net sweeps were taken about 30 minutes after the treatment in the treated area and also in the untreated area adjacent to it.

Table 2.—The mortality of 20 cabbage loopers, caged at various distances in the field from the outlet of the machine, 48 hours after being treated with 7.5 pounds of DDT in 10 gallons of water applied as an aerosol.

Aerosol Particle Size (Microns)	Distance from Outlet in Feet	Per Cent Mortality
30	25	60
30	50	55
20	25	90
20	50	65
Untreated	—	0

The fourth experiment consisted of treating an area in a squash field with 2 ounces of hexaethyl tetraphosphate in 10 gallons of water. This area was approximately 250 feet long. Aphid counts were taken 24 hours later in the treated polt and also in an untreated area adjacent to the treated plot.

In order to improve the effectiveness of the aerosol application, a hood was constructed for confining the fog. The aerosol fog is blown out at right angles from the machine. Two bamboo poles, 3 feet apart, extended horizontally to the side for 20 feet and were covered with white muslin which was prepared in such a manner as to make a 3-foot trailer as the outfit proceeded down the field. The end of the boom which was at a right angle to the machine was open in order to allow the fog to continue to drift in the same direction as before. This hood was used in the remaining four experiments.

The fifth experiment was performed on tomatoes for the control of garden fleahoppers and other tomato insects. The field was divided into 6 plots, each about 300 feet in length. The following treat-

Table 3.—The effect of an aerosol application of a mixture of 2 ounces of 40 per cent nicotine, 2 ounces of 20 per cent pyrethrum extract, and 7.5 pounds of 50 per cent wettable DDT on eggplant insects.

Species of Insects	Number of Insects in 20 Net Net Sweeps 30 Minutes After Treated		
	Treated Area		Untreated Area
	5 Feet from machine	10 feet from machine	5 to 10 feet from machine
White flies		91	57
Lygus bugs			4
Lady beetles	2		2
Cucumber beetles			2
Garden fleahoppers			10
Lacewing flies			1
Moths		8	8

Table 4.—The average number of aphids per squash leaf 24 hours after treatment with 0.03 per cent hexaethyl tetraphosphate water aerosol.

Distance from Aerosol Outlet	Average Number Aphids per Leaf	
	Treated	Untreated
5 Feet	24.4	93.6[1]
10 Feet	68.8	
20 Feet	69.9	

[1] Average of untreated leaves selected 5, 10, and 20 feet in the plot, similar in position to the treated area.

ments were applied: (1) 1 gallon of 25 per cent DDT in 4 gallons of kerosene; (2) 6 fluid ounces of 20 per cent pyrethrum extract in 4 gallons of kerosene; and (3) check or untreated areas. Each treatment was replicated twice. Each plot was divided into 20 foot areas, starting at the edge of the field adjacent to the outlet of the fog machine. Thus the area designated as 0 to 20 is the part of the plot which was covered by the hood during the insecticidal application. The remainder of the plot was treated with the aerosol drift from the end of the hood for 20 to 80 feet as shown in the table. Net sweeps were taken in these areas in order to determine the distance of effectiveness of the aerosol drift.

The sixth experiment was performed on a squash field which was heavily infested with melon aphids. The field was divided into 8 plots each about 200 feet long. The following treatments were applied: (1) 1 gallon of 25 per cent DDT emulsion in 4 gallons of kerosene; (2) 6 fluid ounces of 20 per cent pyrethrum extract in 4 gallons of kerosene; (3) 1 pint of hexaethyl tetraphosphate in 5 gallons of water; and (4) check or untreated plots. Each treatment was replicated twice. Insect counts were taken 24 and 72 hours after treatment application.

The seventh experiment was also conducted in a squash field. The plots were approximately the same size as those in experiment six. The treatments applied here were as follows: (1) 3.75 pounds of 50 per cent wettable DDT in 5 gallons of water; (2) 6 fluid ounces of piperonyl cyclohexenone in 4 gallons of water; (3) 1 quart of 25 per cent rothane emulsion in 4 gallons of kerosene; and (4) check on untreated plots. Each treatment was replicated twice. Insect counts were taken 24 hours and 72 hours after the treatment application.

The final experiment was conducted in a tomato field approximately 2000 feet long and 20 feet wide. This field was divided into eight plots. The treatments used in experiment 7 were applied here and replicated twice. In this experiment, all the treated plants were covered by the hood during the insecticidal application.

Table 5.—Effectiveness of aerosol treatments on tomato insects (as indicated by the average number of insects in 20 net sweeps) at varying distances from the outlet of the fog machine.

Insecticide Treatment	Average Number Insects in 20 Net Sweeps at the Following Distances in Feet							
	24 Hrs. After Treatment				72 Hrs. After Treatment			
	0–20*	20–40	40–60	60–80	0–20	20–40	40–60	60–80
				Garden Flea Hopper				
DDT[1]	1.0	50.0	56.0	139.5	2.0	41.5	193.5	302.0
Pyrethrum[2]	3.5	97.0	214.0	242.0	10.5	184.0	476.5	519.0
Untreated	269.0	286.5	525.5	333.5	525.0	727.0	821.5	714.0
				Lygus Bugs				
DDT	2.0	4.5	11.5	6.0	1.0	0.5	3.5	8.0
Pyrethrum	4.5	6.0	3.0	7.0	1.5	5.0	7.0	10.5
Untreated	7.0	9.0	14.0	13.0	11.5	8.0	20.0	11.0
				Leafhopper				
DDT	0.5	0.0	1.0	1.5	0.5	2.5	4.0	2.5
Pyrethrum	2.0	3.0	1.5	4.0	4.0	14.5	8.0	9.5
Untreated	16.0	8.0	5.0	6.0	23.5	8.0	10.0	8.0
				Cucumber Beetles				
DDT	0.5	0.0	1.0	1.0	0.5	1.0	6.0	7.0
Pyrethrum	1.5	1.5	1.5	1.0	2.5	4.0	7.5	5.5
Untreated	3.0	3.0	2.0	1.5	4.5	10.0	3.0	4.0

* Treated plots 0 to 20 feet covered by the hood.
[1] 1 gallon of 25% DDT emulsion in 4 gallons of kerosene.
[2] 6 fluid ounces of 20% pyrethrum extract in 4 gallons of kerosene.

Table 6.—The control of melon aphids with various insecticides applied as aerosols.

Aerosol Formulation	Average No. of Aphids per Leaf at the Following Distances from the Machine			
	24 Hrs. after		72 Hrs. after	
	10 Ft.	40 Ft.	10 Ft.	40 Ft.
1 gal. of 25% DDT in 4 gal. kerosene	19.3	68.1	24.4	123.5
6 oz. of 20% pyrethrum extract in 4 gal. kerosene	29.7	140.5	36.0	118.9
1 pt. hexaethyl tetraphosphate in 5 gal. water	21.5	104.7	23.7	138.9
Untreated	126.7	136.5	183.1	109.8

Net sweeps were taken 24 and 72 hours after the treatment application.

Discussion of Results.—This machine can produce aerosols in the following sizes: small, 10 microns; medium, 20 microns and large aerosol particles, 30 microns in size. The data in table 1 show that this method of insecticide application gave excellent control of caged cucumber beetles. In spite of the fact that the application was subjected to drift in a 10-mile per hour wind, a good kill was obtained with the large particle size at 20 and 40 feet from the machine and showed some kill as far as 60 feet. The medium aerosol particles were effective only for a distance of 20 feet while the insecticide applied as a small aerosol particle was not effective for this short distance.

The data in table 2 show that both the large and medium aerosol particles of DDT controlled cabbage loopers, *Trichoplusia ni* (Hbn.), equally well for distances of 25 to 50 feet. It may be noted here that all the surviving cabbage loopers treated with DDT pupated during the observation period of 48 hours, indicating that these larvae probably should not have been considered in the mortality records.

The aerosol method of applying insecticides gave excellent control of the garden fleahopper, *Halticus bracteatus* (Say), especially in the plots where the hood was used. This is shown in tables 5 and 8. DDT, pyrethrum, piperonyl cyclohexenone, and *Rothane* all gave excellent control of this garden pest.

Control of the melon aphid, *Aphis gossypii* (Glov.), was rather erratic, and this may be due either to the insecticides used or to an insufficient amount of the insecticide. Table 6 shows that 72 hours after the treatment application the average number of aphids per squash leaf was 87 per cent less on the DDT treated plots at 10 feet than on the untreated areas. Numerous dead aphids were seen under the squash leaves of the treated plants while none were found in the untreated plots. The new insecticide, hexaethyl tetraphosphate, was as effective as the DDT emulsion or pyrethrum. Table 7 shows that a water suspension of DDT or the *Rothane* were of little value in reducing the aphid infestation even though a hood was used.

In the Lower Rio Grande Valley strong winds are a factor in all insecticidal applications. During the performance of these experiments the wind varied from 5 to 12 miles per hour. The aerosol fog was applied in the same direction as the wind was blowing in all the experiments except No. 8 which was against the wind. Observations show that many times the wind tends to lift the aerosol fog away from the ground at about 10 feet or less from the outlet of the machine. These observations were confirmed in experiments 3 and 4. The best control of white flies was obtained only 5 feet from the machine (Table 3), and there was no apparent control 5 feet farther away. Again without the use of the hood, the aerosol fog gave good control of aphids only at the 5-foot distance as is shown in table 4. Confining the fog under the hood increased the distance of effectiveness of the fog as is

Table 7.—The average number of melon aphids found on a squash leaf in the area covered by the hood during the aerosol treatment.

Aerosol Formulation	Ave. No. Aphids per Leaf After Treatment	
	24 Hours	72 Hours
3¾ lbs. of 50% DDT in 5 gal. water	157.2	189.6
6 oz. of Piperonyl Cyclohexenone in 5 gal. kerosene	114.3	144.0
1 qt. of 25% *Rothane* emulsion in 5 gal. kerosene	74.2	313.0
Untreated	281.9	205.2

Table 8.—**The control of tomato insects with various insecticides applied as aerosols under a hood.**

Insecticide	Average Number of Insects in 20 Net Sweeps After	
	24 Hrs.	72 Hrs.
	Garden Fleahoppers	
DDT[1]	3.5	1.5
Piperonyl Cyclohexenone[2]	5.0	10.5
Rothane[3]	3.5	1.0
Untreated	85.0	49.0
	Lygus bugs	
DDT	2.5	4.0
Piperonyl Cyclohexenone	1.0	4.0
Rothane	1.5	5.0
Untreated	19.0	5.0
	Leafhoppers	
DDT	0.5	2.0
Piperonyl Cyclohexenone	0.0	0.0
Rothane	0.5	2.0
Untreated	16.0	2.5
	Cucumber Beetles	
DDT	0.0	0.0
Piperonyl Cyclohexenone	0.5	2.0
Rothane	2.5	0.0
Untreated	3.5	3.0

[1] 3.75 lbs. 50% wettable DDT in 5 gallons of water.
[2] 6 fluid ounces of piperonyl cyclohexenone in 4 gallons of kerosene.
[3] 1 quart of 25 per cent *Rothane* emulsion in 4 gallons of kerosene.

shown in the aphid reduction counts in table 6. In this table the data show that the aphids in the area covered by the hood were effectively controlled, but that the drift beyond the hood had very little effect on the aphid population. The 72-hour counts in table 5 show that both DDT and pyrethrum were very effective in controlling garden fleahoppers in the 0 to 20 foot area covered by the hood. The DDT drift was much more effective in the 20 to 80 foot areas than the pyrethrum fog. In the area 40 to 60 feet away from the aerosol machine DDT reduced the garden fleahopper population approximately 75 per cent while pyrethrum showed a 42 per cent reduction. In the same experiment DDT and pyrethrum were equally effective in controlling lygus bugs in the area covered by the hood. As can be seen in the 72-hour counts of table 5 DDT again was more effective than pyrethrum in controlling lygus bugs 20 to 60 feet away from the machine. These data indicate that the effective distance of an aerosol drift is influenced to some extent by the insecticide used.

In experiment 8 the fog application was made directly against a 12 mile wind. The hood was used here and the data in table 8 show that effective control of garden fleahoppers was obtained.

Many of the insecticides in these experiments were mixed with kerosene. To date no injury has been noticed where the kerosene form of the aerosol had been applied to the various garden crops.

SUMMARY.—Garden fleahoppers were successfully controlled with DDT, *Rothane*, piperonyl cyclohexenone, and pyrethrum aerosols. The new insecticide, hexaethyl tetraphosphate applied as an aerosol was as effective as the DDT aerosol in controlling melon aphids.

The aerosol application was most successful in the treated area near the outlet of the machine, especially when a hood was used. The data also indicates that the effective distance of the aerosol drift is determined to a certain extent by the type of insecticide used. A hood for confining the aerosol fog appears to be necessary for good insect control on windy days.

Preliminary experiments seem to indicate that the large aerosol particle, 30 microns or more in size, is the most effective size.

Observations showed that the kerosene used as an aerosol media did not injure tomato, squash, or cabbage foliage.—4-23-47.

LITERATURE CITED

Bronson, T. E., and Floyd F. Smith. 1946. Control of aphids on potatoes in northeastern Maine, JOUR. ECON. ENT. 39(2): 189–94.

Collins, D. L., and R. D. Glasgow. 1946. DDT thermal aerosol fogs to control clothes moths in a wool storage warehouse. JOUR. ECON. ENT. 39(2): 241–5.

Ditman, L. P., Lyle D. Goodhue, Floyd F. Smith and George Burkhardt. 1946. Insecticidal aerosols for pea aphid control—second report. JOUR. ECON. ENT. 39(2): 199–204.

Glasgow, Hugh. 1946. DDT as a control for pea aphid. JOUR. ECON. ENT. 39(2): 195–9.

Glasgow, R. D., and D. L. Collins. 1946. The thermal aerosol fog generator for large sale application of DDT and other insecticides. JOUR. ECON. ENT. 39(2): 227–35.

The Response of California Red Scale to Fumigation with Ethylene Dibromide and Ethylene Dibromide-HCN[1]

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Ethylene dibromide or dibromoethane, a colorless liquid at room temperature, boils at 131.7° C. and melts at 10° C. In the gas phase it is approximately six times heavier than air. As a fumigant, Neifert *et al.* (1925) found it to be the most effective bromide tested against grain weevils. Roark & Cotton (1929) found it to be fairly toxic to the rice weevil, but did not include it among the first 18 out of some 200 compounds tested.

More recently, Mason & Chisholm (1945) reported ethylene dibromide to be highly effective against all stages of the Japanese beetle. They state that F. E. Baker noted the toxicity of this compound to Japanese beetle larvae as early as 1930. The Dow Chemical Company has found ethylene dibromide to be effective as a soil fumigant against wireworm, nematodes, and the seed-corn maggot. Lange (1945), also, found ethylene dibromide to be effective against the wireworm. Richardson (1945) tested ethylene dibromide on cadelle beetles buried in dry corn, and found the toxicity similar to that of 1, 1-dichloro-1-nitroethane.

In a search for new fumigants with which to control scale insects on citrus, the writers have tested ethylene dibromide[4] and have found it to be relatively toxic to the California red scale, *Aonidiella aurantii* (Mask)., in comparison with many other organic compounds tested. Results of experiments with ethylene dibromide and with hydrocyanic acid gas (HCN) alone and in combination are reported in the present paper.

METHODS.—For these experiments, grapefruits were infested with nonresistant and resistant strains of red scale from stock cultures, as previously described (Lindgren 1938), and were held under identical conditions until the insects were ready for fumigation treatment. In each test 200 scales of each strain were used, and unless otherwise stated the insects were mature females treated just prior to the production of young. Four to six tests were generally conducted at each dosage, and all mortality counts were made three weeks after treatment.

All fumigations were conducted in a 100-cubic-foot fumatorium maintained at a temperature of 75° F., a 10-inch fan providing necessary circulation. Three methods were used in volatilizing the ethylene dibromide: (1) the fan was set to blow over an absorbent material on which the fumigant had been applied, (2) the fumigant was vaporized with the aid of a hot plate, or (3) it was vaporized in a flask and the gas was drawn into the chamber. Results indicated that the methods were equally effective. No difficulty was encountered in vaporizing hydrocyanic acid by method 1, since it boils at 25.2° C.

Table 1.—Mortality from fumigation of various developmental stages of non-resistant and resistant strains of California red scale with ethylene dibromide and with hydrocyanic acid. Exposure, 45 minutes, at 75° F.

STAGE	ETHYLENE DIBROMIDE, 7.7 MG. LITER		PERCENT KILLED HYDROCYANIC ACID, 0.37 MG./LITER	
	Non-resistant	Resistant	Non-resistant	Resistant
First instar (nipple stage), 55 days old	86.0	89.0	99.6	93.9
First molt, 8 days old	87.0	90.5	97.2	82.4
Second instar, 13 days old	93.0	99.0	97.1	68.9
Second molt, 16 days old	89.0	93.5	97.2	41.5
Early gray adult, 21 days old	91.0	89.5	92.1	47.8
Late gray adult, 30 days old	87.5	97.2	99.8	81.0
Adult female, 38 days old	93.3	94.0	99.4	81.7

RESULTS.—In table 1 the results of fumigating nonresistant and resistant strains of red scale in various stages of development, with ethylene dibromide and with HCN, are shown for comparison. Ethylene dibromide was effective in killing both strains of red scale, the general tendency being toward a slightly higher percentage of mortality in the resistant strain. There was not a great deal of difference in the kill of the various age

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[4] Furnished by the Dow Chemical Company through the courtesy of Dr. J. F. Kagy.

groups, and it is difficult to say which is the most susceptible. When HCN was used as the fumigant, the difference in kill between the two strains of scale was notable, and also the differences between the various age groups.

Although practically 100 per cent of the adult female resistant and nonresistant red scales were killed when fumigated with ethylene dibromide at a concentration of 15.5 mg./liter (Table 2), it was found that many young had settled on the fumigated fruits and were developing. Since the scales were fumigated a day before the young were due to emerge, no young were present at the time of fumigation. So far as we have been able to determine, these young were born after the females had been fumigated and before they died. Close observation of the adult scales under a microscope indicated that they lived 4 to 6 days after fumigation and produced young. Movements within the bodies were discernible until about the fourth to sixth day after fumigation, and living young appeared under the females until this time. After the seventh day, no further movement could be detected and no more young were produced.

Table 2.—Mortality from fumigation of nonresistant and resistant strains of adult female California red scale with ethylene dibromide, hydrocyanic acid, and mixtures of ethylene dibromide and HCN. Exposure, 45 minutes, at 75° F.

FUMIGANT (MG./LITER)	PERCENT KILLED	
	NONRESISTANT	RESISTANT
Ethylene dibromide 7.7	90.0	92.0
Ethylene dibromide, 15.5	99.5	99.8
HCN, 0.1	76.0	28.0
HCN, 0.2	95.0	50.0
HCN, 0.1; ethylene dibromide, 7.7	70.0	32.0
HCN, 0.1; ethylene dibromide, 15.5	70.0	35.0
HCN, 0.2; ethylene dibromide	98.0	48.0

Since HCN is very toxic to the young red scale, it was thought that it might be possible to mix HCN and ethylene dibromide and kill all stages of the red scale with a relatively low dosage of each material. The results of tests with these two fumigants used alone and in combination are shown in table 2. It is evident from the data that when the red scales were fumigated with a mixture of HCN and ethylene dibromide, the latter had very little or no effect, even at very high concentrations (23.1 mg./liter). A concentration of 15.5 mg./liter ethylene dibromide used alone killed 99.5 per cent of the nonresistant and 99.8 per cent of the resistant scale, whereas 0.1 mg./liter HCN killed 76 per cent of the nonresistant and 28 per cent of the resistant scale. When the scales were fumigated with a mixture of 0.1 mg. HCN and 15.5 mg. ethylene dibromide per liter, 70 per cent of the nonresistant and 35 per cent of the resistant red scale were killed, these results being comparable to those obtained with 011 mg./liter HCN used alone. When a mixture of 0.2 mg. HCN and 23.1 mg. ethylene dibromide per liter was used, the kill of red scale was very similar to that obtained when only 0.2 mg./liter HCN was used. In the presence of HCN the ethylene dibromide therefore had little or no toxic effect on red scale.

To explain the ineffectiveness of the ethylene dibromide under these conditions, it was suggested that possibly the HCN and ethylene dibromide reacted to form a nitrile; but the proportion of HCN to ethylene dibromide in these tests was so small that only a small portion of the ethylene dibromide would be used up in such a reaction, although all the HCN would be used if the reaction went to completion. Since the kill obtained with HCN plus ethylene bromide was of the same magnitude as that obtained with HCN alone (Table 2), it is evident that HCN was present.

To eliminate to some extent the factor of chemical reaction, and to determine whether the HCN had some stupefying effect that prevented the insects from getting any ethylene dibromide, a series of experiments was set up. These experiments were similar to those used to measure "protective stupefaction" (Gray & Kirkpatrick 1929) with HCN, except that in this case the insects were exposed to a low concentration of HCN for 5 minutes prior to the regular fumigation with ethylene dibromide. The HCN was removed from the chamber after the 5-minute exposure, and the ethylene dibromide dosage was applied. The results (Table 3) show that red scales exposed to

Table 3.—Mortality from exposure of nonresistant and resistant strains of adult female California red scale to a low dosage (stupefying charge) of HCN (exposure, 5 minutes, at 75° F.) prior to fumigation with ethylene dibromide (exposure, 45 minutes, at 75° F.).

FUMIGANT		PERCENTAGE KILL	
HCN (Stupefying Charge), Mg./Liter	Ethylene Dibromide, Mg./Liter	Nonresistant	Resistant
0.0	3.8	29.0	16.0
0.0	7.7	90.0	92.0
0.0	11.5	99.7	99.7
0.0	15.5	99.5	99.8
0.1	7.7	41.3	35.5
0.1	15.5	76.3	71.0

a low concentration of HCN prior to fumigation with ethylene dibromide are much more difficult to kill than those that have not received the conditioning treatment with HCN. This same phenomenon has been well demonstrated in tests in which HCN was used as both the stupefying and the lethal charge (Lindgren 1938).

SUMMARY.—Ethylene dibromide was tested as a fumigant on resistant and nonresistant strains of the California red scale, *Aonidiella aurantii* (Mask.). There was no difference in kill between the nonresistant and resistant strains of red scale, and there was very little difference in the susceptibility of the various stages of red scale, when fumigated with ethylene dibromide. The results of fumigation of both strains of red scale with hydrocyanic acid gas are given for comparison.

Although practically all of the adult red scales fumigated with a dosage of 15.5 mg. of ethylene dibromide per liter died, they lived long enough after fumigation to produce young.

When mixtures of ethylene dibromide and hydrocyanic acid were used as the fumigant, the toxic effect appeared to be from the HCN and not from the ethylene dibromide. The percentage kill of red scale fumigated with these mixtures was in the same range as that from fumigation with HCN alone, although in many instances the dosage of ethylene dibromide in the mixture was very high.

Red scales exposed to a low (stupefying) dosage of HCN prior to fumigation with ethylene dibromide were more difficult to kill than those not receiving the HCN conditioning treatment.—5-5-47.

LITERATURE CITED

Gray, G. P., and A. F. Kirkpatrick. 1929. The protective stupefaction of certain scale insects by hydrocyanic acid vapor. JOUR. ECON. ENT. **22:** 878–92.

Lange, W. H., Jr. 1945. Ethylene dibromide and dichloropropane-dichloropropene mixture for wireworm control. JOUR. ECON. ENT. **38:** 643–5.

Lindgren, D. L. 1938. The stupefaction of red scale, *Aonidiella aurantii*, by hydrocyanic acid. Hilgardia **11**(5): 211–25.

Mason, A. C., and R. D. Chisholm. 1945. Ethylene dibromide as a fumigant for the Japanese beetle. JOUR. ECON. ENT. **38:** 717–8.

Neifert, I. E., F. C. Cook, R. C. Roark, W. H. Tonkin, E. A. Back, and R. T. Cotton. 1925. Fumigation against grain weevils with various volatile organic compounds. U. S. Dept. Agr. Dept. Bul. **1313:** 1–40.

Richardson, C. H. 1945. Fumigants for the cadelle in shelled corn. JOUR. ECON. ENT. **38:** 478–81.

Roark, R. C., and R. T. Cotton. 1929. Tests of various aliphatic compounds as fumigants. U. S. Dept. Agr. Tech. Bul. **162:** 1–52.

JAMES AND TELFORD GO TO WASHINGTON STATE

Mr. Morris T. James, for several years a member of the faculty and research staff at Colorado Agricultural College and Experiment Station, has been appointed to a similar position at Washington State College, Pullman. Dr. Horace S. Telford, who has been conducting research in control of pests of domestic animals for Dr. Hess & Clark, Ashland, Ohio, has also accepted an appointment of Pullman where he will be on the entomological staff of Washington State College.

Quantitative Methods in Biological and Control Studies of Orchard Mites

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One of the principal obstacles to studies of populations of orchard mites is the problem of making an accurate determination of the density of the population. Various methods have been devised, ranging from rough qualitative estimates (*e. g.* Newcomer, 1936) and direct counting (*e. g.* Baten & Hutson, 1943) to more elaborate ones involving removal of the mites and eggs by boiling or brushing, and counting those found in a known fraction of the total sample. Qualitative estimates, when carefully made, require just as much time as more precise methods and yield results which are impossible to treat statistically. Direct counts can be made when the populations are very low, but even then they are less accurate than good aliquoting techniques since few leaves can be sampled, and they are obviously hopeless when total populations as high as 2000 mites and eggs per leaf are encountered as in the heaviest populations of *Tetranychus pacificus* McGregor on apple in central Washington. In such cases there is no alternative to the use of some aliquoting method if statistically workable data are to be obtained.

Jones & Prendergast (1937) described a method for determining the population density of *Paratetranychus citri* McGregor on citrus trees, involving removal of the mites and eggs with hot sodium hydroxide solution, drawing off a known fraction of the sample under constant agitation, and counting the number of individuals found. Attempts to adapt this technique to the study of *Tetranychus pacificus* on apples showed that it was somewhat cumbersome in certain respects, and also was not as well suited to use with *T. pacificus* as with the species for which it was designed. The problems encountered in the two species are very different for *T. pacificus* spins a profuse web, apple leaves are more irregular and pilose on the under side than are citrus leaves, the trees usually are larger and less compact, and because of these conditions the infestation on individual leaves is more likely to show variations. The procedure finally developed involves (1) selection of leaf samples, (2) removal of mites and eggs by shaking in a soap solution, (3) reduction of residue by screening, (4) removal of a known fraction of the sample under constant agitation, and (5) counting the mites and eggs in this fraction. Advantages of the technique described here are reliability, simplicity of the apparatus, omission of heat and disagreeable reagents, and the excellent condition of preservation of the mites.

DETERMINATION OF POPULATION DENSITY.—The writer has sampled plots ranging from one-half to five trees and has found the results replicable within 5 per cent in most cases. Fifty-six leaves from half trees, 100 from one or two tree plots, and 200 from 5 tree plots were found adequate. In the case of half trees, the portion of the tree sampled was tagged if sampling was to be repeated, and in the larger plots likewise it was found that results were more consistent if exactly the same number of leaves was removed from each portion of each tree in successive samples. Sampling was not entirely random, for primary leaves and small immature leaves were avoided except early in the season when no others were available. So far as possible the leaves from each tree were of nearly the same size. The leaves were placed in gallon cans with tight covers and returned to the laboratory.

The mites and eggs are removed with a dilute solution of monoethanolamine oleate made as follows: 25 ml. of monoethanolamine are stirred into 2500 ml. of water with a high speed mixer, followed by 100 ml. of oleic acid (commercial grades). From 150 to 175 ml. of this soap in 2 liters of water are used for each sample. The solution is poured over the leaves, the cover placed on the can, and the can is shaken 35 to 40 times. The leaves are then removed to a deep pan and rinsed individually with a hard, needle spray. In order to eliminate the coarse leaf particles, spray residue and dust, the sample is then

[1] The writer wishes to acknowledge his indebtedness to Dr R. L. Webster of the State College of Washington, and to Dr. James Marshall of the Dominion Entomological Laboratory, Vernon, British Columbia, for valuable assistance given during the course of this work, which was conducted at the Tree Fruit Branch Experiment Station, Wenatchee, Washington.

washed through a pair of screens having openings of 600 and 90 micra, after which the residue on the finer screen is washed into an 800 ml. beaker on which the 800 ml. mark has been carefully calibrated. Reduction of residue is of great importance since it simplifies the problem of counting. In adapting the technique to other animals, screens with different size openings can be used.

About 30 ml. of soap are then added to the sample in the beaker, and the volume is brought to 800 ml. with tap water in preparation for aliquoting. The apparatus used in aliquoting (Fig. 1) is mounted on a shelf (A) so that the calibrations are at eye level, and in such a position that there is a good source of light from the side opposite the operator. The sample is agitated with an S-shaped metal paddle (B) mounted in the end of a metal rod (C) and operated by an electric motor (D). Two sheet metal baffles (E) attached by stiff wire to a weighted board (F) accelerate vertical mixing, and prevent whirling of the sample over the beaker rim. To prevent rotation of the baffle assembly, a nail (G) is driven into the end of the board, and this rests against the ring stand (H). The aliquot is removed from the sample by means of a sampling tube (I) made from a 14 cm. length of glass tubing, 2 mm. inside diameter, with three holes blown in the side. The aliquot is drawn into a calibrated test tube (J) by means of a low grade vacuum produced by allowing water to siphon from the vacuum jar (K) past the pinchcock (L). To insure the same degree of vacuum, the jar is filled to the same level for each sample; also the jar is large so that the drop in water level while drawing off the aliquot is small enough that there is no significant change in vacuum during the course of aliquoting. The inlet tube (M) must pass through the rubber stopper obliquely so that the incoming water strikes the wall of the test tube at an angle, otherwise the water falls directly downward, resulting in foaming. In taking an aliquot, the calibrated test tube is placed in a hole in the shelf and rests on the support (O), and the stopper (P) is placed in the tube. When the sample has been stirred for 30 seconds, the pinchcock (L) is opened, and the sampling tube (I) is lowered quickly into the beaker, with the openings facing directly into the current and moved slowly inward and outward between the center and wall of the beaker. When the desired volume has been removed (50, 80 or 100 ml.) the rubber tube at N is pinched shut quickly, the pinchcock (L) is released, and the stopper (P) is removed. The portion of the sample still in the tube (N) is allowed to drain back into the beaker, and the apparatus is washed and prepared for the next sample.

The number and size of the aliquots is

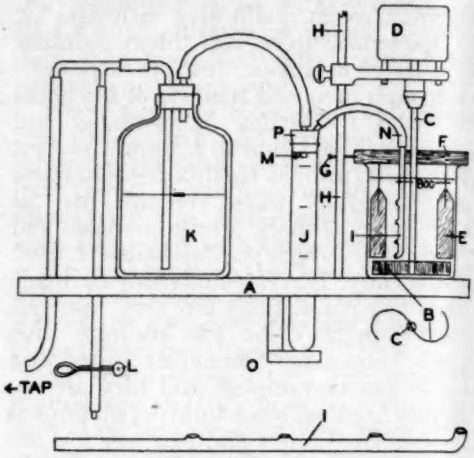

FIG. 1.—Apparatus used in aliquoting. Explanation in text.

determined by the density of the population, the number of leaves used, and the amount of residue in the sample. In practice the writer attempted to keep the number of mites counted around 200 per sample, varying the number and size of the aliquots to approach this figure. This means that the total sample counted may vary from 0.25 to as little as 0.001. As a rule it was necessary to take at least two successive aliquots, and occasionally three in the densest populations, or in samples of 200 leaves. Using three aliquot sizes (50, 80, 100 ml.) it is possible to obtain virtually any desired fractional reduction of the original sample. When successive aliquots are required, the first one is placed in a beaker, the volume made up to 800 ml. with water and 25–30 ml. of soap, and a second one taken as before. This may be repeated again if necessary. When the desired reduction has been obtained, the mites are allowed to settle to the bottom of the test tube, the supernatant fluid is carefully siphoned off, and the mites are transferred to a counting chamber consisting of a glass or plastic dish with a

ridged bottom to prevent movement of the mites. Counting is done with a wide field stereoscopic microscope, using bright illumination and viewing the mites with reflected light.

Outside of careful sampling and aliquoting, the key to dependable results in either biological or control studies is accurate interpretation in counting. The observer must be able to distinguish between living and dead mites and eggs, and at least in control studies must be able to identify larvae, protonymphs, deutonymphs, and adults. Distinguishing living from dead eggs is perhaps the most difficult problem, and the problem is further complicated by the fact that the dead eggs (and mites as well) which could be readily distinguished on the tree by their shrivelled appearance usually regain their original shape after a few hours in the washing solution. The following criteria will help in many cases so far as species of *Tetranychus* are concerned, but they are no substitute for a first-hand acquaintance with the mites, which can be acquired only by many days of observations in the field, and especially through rearing studies.

1. Eggs probably living.
   a. Translucent watery white, homogeneous (newly laid).
   b. Differentiated into a translucent water white and a light amber portion, both portions homogeneous (embryogeny somewhat advanced).
   c. Light amber, translucent, completely homogeneous, eye spots may be present (development 0.5 to 0.75 per cent completed).
   d. Dark amber, with sharply defined, bright red eye spots, shape sometimes irregular (eggs nearly completely developed).
   e. Greatly expanded, gelatinous, chorion absent (eggs ruptured, or possibly expelled from female before completely formed).
2. Eggs probably dead.
   a. Transparent, colorless.
   b. Transparent, brownish, homogeneous, eye spots absent or poorly defined.
   c. Brownish, with irregular transparent and translucent patches, eye spots absent or poorly defined.
   d. Translucent, eye spots "muddy" red, indistinct.

Distinguishing living from dead mites is not difficult, even when the original shape of the dead mites is restored by soaking. After one becomes acquainted with the appearance of the normal, healthy mite, most specimens that were living at the time the sample was taken will be recognized immediately in the counting chamber. Borderline cases are separated on the basis of the color of the body and eye spots. In *Tetranychus pacificus* the most significant post mortem changes are the deterioration of the carmine eye spots and of the rich greenish or yellow color of the body contents. The body contents become brownish green or brown, the black excretory pellets are scattered indiscriminately throughout the body, and the eye spots become brownish and disintegrate readily in the washing solution. If the mite has been dead for some time it is completely colorless. Occasionally mites will be crushed in the washing process, but these can be distinguished by the presence of unchanged chlorophyll and the bright carmine color of the eye spots, even though the latter may be broken up occasionally. Newly hatched larvae contain no chlorophyll. Males are usually a dull orange or yellowish, but the eye spots are still diagnostic.

In population studies the differentiation between egg and mite may be adequate for many cases, reducing the problem of counting to determining whether the mites were dead or alive at the time of sampling. In exacting studies of the quantitative characteristics of populations, however, and also in critical studies of field mortality it is not only desirable but necessary to identify the various stages. There are a few absolute criteria that can be advanced, but beyond these the work is subject to the interpretation of the observer, and it is again obvious that there is no substitute for a first-hand acquaintance with the mites, obtained through rearing studies. The stages distinguishable by absolute criteria are the egg, larva (six legs), and adult (external genitalia of female, and occasional characteristic flexure of tip of opisthosoma of male). The criteria used in distinguishing the first two are satisfactory, but distinction of the adults on the basis of the genitalia is impractical for present purposes, especially in the case of males. Fortunately the appearance of the adult males and females is so char-

acteristic that borderline decisions are rarely necessary. The bright yellow color of the non-feeding adult female is an absolute criterion that is sometimes useful. In differentiating between protonymphs and deutonymphs, the features of greatest value are size, turgidity, color, and shape. Size alone is usually sufficient to distinguish young protonymphs from old deutonymphs, and it is in between these points that decisions become difficult. One must recall the progressive changes taking place in each active stage (especially increase in size, increase in turgidity, increasing intensity of green coloration) to decide whether a particular specimen is an old protonymph or a young deutonymph. For example, suppose two nymphs of approximately the same size but presumably different instars are to be distinguished. One is gray or pale green, and rather flaccid; the other is dark green and turgid. The first is likely a young deutonymph, the second an old protonymph. The similarity between active female deutonymphs and adult males is sometimes very close, but the longer legs of the male, its ruddier color, and its more conical opisthosoma (frequently with the end curved upward) will nearly always distinquish it from the female deutonymph. Aside from these brief comments there is little that can be offered to assist one as yet unfamiliar with the life history of the species and the appearance of the various stages.

Tallying is done with a battery of mechanical counters operated by foot and by hand, the hands being left as free as possible for manipulating the counting chamber and a needle. When tallying is completed, the results are tabulated, along with the appropriate field data, and a record of the aliquots taken. The results may be expressed in terms of mites per leaf, or mites per square centimeter, or in other terms depending upon the nature of the work. If in terms of mites per leaf, the number of mites and eggs (or of separate instars if this is necessary) counted in the sample is multiplied by the inverse of the fraction of the total sample counted, and divided by the number of leaves. For example, if a 100 leaf sample was washed, two successive 100 ml. aliquots (each one-eighth of total sample) were taken, the second containing 235 mites and 192 eggs, then the entire sample contained 8×8× 235 mites and 8×8×192 eggs. Dividing these values by 100, the density of the population is found to be 150.4 mites and 122.9 eggs per leaf.

DETERMINATION OF FIELD MORTALITY.—It is obvious that one could obtain a general idea of the mortality sustained by a given population of *T. pacificus* following the application of sprays or dusts by determining the population density just before and a few days after the application. However, one example from the writer's experience should show that this simple procedure is inadequate in critical studies. In this one case a rotenone and kerosene mixture was applied May 13, 1940 to reduce an extremely heavy infestation of overwintered females on water sprouts in an orchard in East Wenatchee, Washington. The data obtained from the first sample were: mites per leaf 116.1, eggs per leaf 13.6, total population per leaf 129.7. A second sample taken several days after spraying showed that there were 6.4 mites per leaf, representing a favorable reduction of 95 per cent of the original population. Later tests at the Tree Fruit Branch Experiment Station orchard showed that with summer infestations (350 to 400 mites, 175 to 200 eggs per leaf) the same mixture again produced 95 to 96 per cent mortality of the mites, but only 50 to 60 per cent of the eggs, and 82 per cent of the total population on the trees when the tests were carried out. This shows that the excellent control (in terms of *reduction of total population*) obtained in the first case was deceptive since it was due solely to the high ratio of mites to eggs present at that time of the season. Since egg mortality is characteristically and significantly lower than mite mortality, and since different compounds and mixtures differ in their relative acaricidal and ovicidal properties, then one must be able to distinguish between egg and mite mortality. The following account describes a procedure developed by the writer for making this distinction.

The technique is based upon life history studies which are too extensive to present here except in graph form (Figs. 2, 3). The data upon which these graphs were based were obtained by rearing mites individually in plastic cells attached to leaves of Delicious apples at the Tree Fruit Branch Experiment Station in Wenatchee (1938-1940). Continuous temperature records

were kept, and observations were made at hourly or bi-hourly intervals. The graphs are based only upon those individuals in which the duration of one or more instars is known to ±2 hours. A total of 170 mites was used, 50 providing information on all seven developmental instars (egg, active larva, quiescent larva, active protonymph, quiescent protonymph, active deutonymph, quiescent deutonymph), the remainder providing information on from one to six of the instars. It was found that the differences in length of the larval and nymphal instars were so slight that for all practical purposes they could be plotted together, and this has been done in Fig. 2. The numbers by the encircled points in that graph indicate the number of individual observation used to determine the points. Likewise in figure 3 the numbers along the curve show the number of eggs used in determining each point.

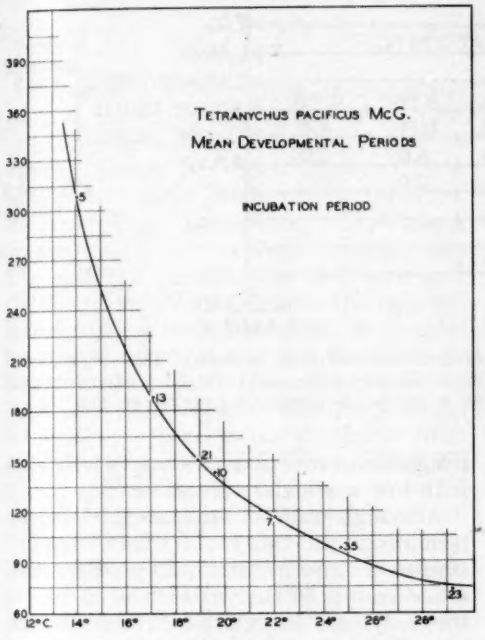

FIG. 2.—Duration of active quiescent larval or nymphal stages under field conditions.

From an examination of the graphs of the duration of the incubation period and the larval and nymphal instars it can be seen that at the normal summer temperatures prevailing in the Wenatchee district (22–26°) C. at the time of year that acaricidal studies are normally conducted, that the incubation period is very slightly more than four times the length of one of the active or quiescent instars. This means that if a particular egg hatches at the same time a second is laid, then by the time the second egg hatches the first mite will have developed to the active deutonymphal stage. This relationship is represented diagrammatically in Fig. 4 which shows the stage to which any given instar present on the tree at the time of spraying will have advanced after an interval equal to the incubation period (99 hours) at 23.9° C. Likewise one can state quite definitely that a quiescent deutonymph under these conditions was in all probability a quiescent larva 99 hours before, and that all mites which are adults at present must have been no younger than quiescent larvae 99 hours before. Therefore we can predict what instar any given mite will attain at a given mean temperature and after a specific time interval, and conversely we can determine what stage a particular mite must have reached at any mean temperature a given number of hours before. At lower temperatures, and for different species, a different relationship between incubation period and later development will pertain, and calculations must be modified accordingly.

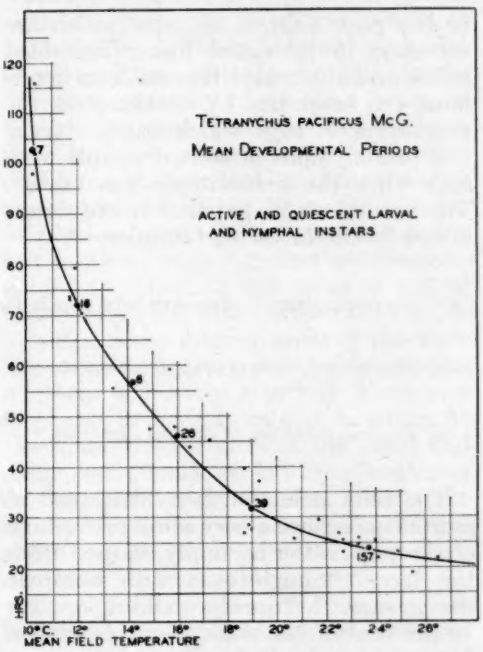

FIG. 3.—Duration of incubation period under field conditions.

The following is an outline of the procedure used for determining mortality in field control studies of *Tetranychus pacificus* in central Washington.

1. First sample collected immediately prior to spraying. Population density expressed in terms of mites and eggs per leaf.
2. Accurate temperature record kept.
3. Second sample taken after length of time equal to incubation period at prevailing temperature. Stages segregated into three groups: eggs, larvae and protonymphs, deutonymphs and adults.

The time interval between the first and second samples permits the development of the post mortem changes which are necessary to distinguish living from dead mites, and also makes it possible to determine egg mortality by checking on the proportion of eggs which hatch (larvae and protonymphs of second sample were eggs when the first sample was taken). The reductions in population are determined by the following formulae.

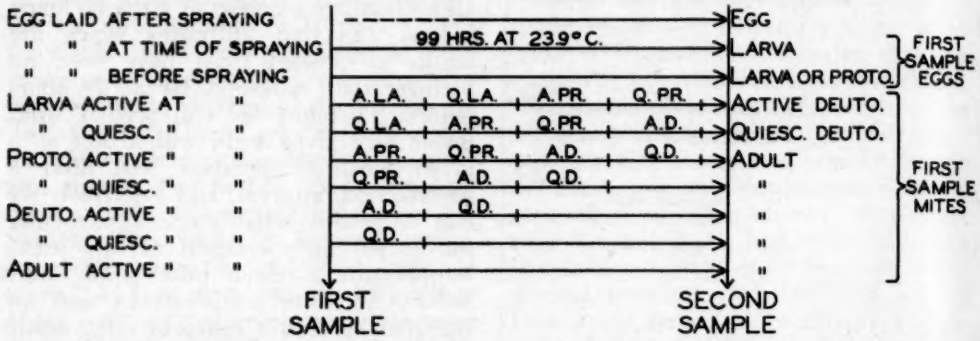

FIG. 4.—Diagram showing basis of procedure in determination of field mortality. The stages shown at the left will have advanced to the corresponding stages shown at the right 99 hours after sampling and spraying at a mean temperature of 23.9° C. (99 hours is the incubation period at 23.9° C.).

(1) Per cent reduction of original total population $= 100 - \frac{\text{total mites per leaf after spraying}}{\text{total mites plus eggs before spraying}}$

(2) Per cent reduction of original mites $= 100 - \frac{\text{total deutonymphs plus adults per leaf after spraying}}{\text{total mites per leaf before spraying}}$

(3) Per cent reduction of original eggs $= 100 - \frac{\text{total larvae plus protonymphs per leaf after spraying}}{\text{eggs per leaf before spraying}}$

The term reduction is used instead of mortality because a very samll percentage of the population is simply washed from the tree, although tests with nontoxic sprays show that rarely would more than 10 per cent of the population be washed from the tree by hydraulic action, execpt by extreme overspraying. Furthermore when toxic mixtures are used the mortality of those mites washed from the tree would be approximately equal to that in the population left on the tree. Accordingly, if a particular mixture were capable of producing a 90 per cent mortality of the total population, and 10 per cent of the original population was washed from the tree, then the effectiveness of the material in terms of reduction would be 91 per cent as compared with the true mortality of 90 per cent, assuming 90 per cent mortality of the mites washed off. Errors introduced by hydraulic removal would therefore be insignificant except in the case of mixtures with low acaricidal values.

Although indirect, this method of determining mortality in field control studies is more satisfactory than any other known to the writer, and in fact is the only one known which enables the investigator to discriminate between egg and mite mortality. It has been used extensively by the author at the Washington State Experiment Station with satisfactory and reproducible results. A liberal budget for a single analysis by an experienced operator is approximately 45 to 50 minutes, allowing 10 minutes for marking and sampling, 10 for washing, 5 to 10 for aliquoting, and 20 to 25 for counting.

With the aid of a capable assistant, as many as 15 separate analyses have been made in a day. Accurate counts usually can be made as long as three days after the samples are washed, although best results are obtained if counting is done immediately. Many mites remain alive in the washing solution for as long as two days, exhibiting a sporadic twitching of the legs.

LITERATURE CITED

Baten, W. D., and Ray Hutson. 1943. Precautions necessary in estimating populations of small animals. JOUR. ECON. ENT. 36(4): 501–4.

Jones, L. S., and D. T. Prendergast. 1937. Method of obtaining an index to density of field populations of citrus red mite. JOUR. ECON. ENT. 30(6): 934–40.

Newcomer, E. J. 1943. Apparent control of the Pacific mite with xanthone. JOUR. ECON. ENT. 36(2): 344–5.

The Balsam Woolly Aphid in Maine

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The balsam woolly aphid *Adelges piceae* Retz. is the most destructive insect pest of balsam fir in Maine. Destruction of fir by this insect has been reported from Vermont, New Hampshire, Quebec, Maine, New Brunswick, and Nova Scotia, with a more extended distribution. The heaviest mortality is in Maine and the Maritime Provinces with the greatest loss occurring from 1930–1934. Probably of Asiatic origin, it was first found to be destructive in Maine, near Brunswick, in 1908 by A. D. Hopkins (Kotinsky 1916). Studies were carried on in Maine from 1932–1934 by Peirson & Gillespie (1934). This paper is based on sixteen years of observations and some research work on this insect. Individual tree data have been secured from a series of eight quarter-acre plots, established on Mount Desert Island, and in Waltham and Indian Town in 1934–1935, and eight established in 1942 in the interior of Maine from Springfield to Weld. The distribution and severity of attack are closely dependent on conditions of growth and subzero temperatures.

Distribution is not state-wide but extends roughly over the southern half of Maine. Weston, Danforth, Sebec, Brighton, Kingfield, Weld, and Bethel approximately mark the northern limit of distribution. The scanty fir on the sandy pine-lands of southwestern Maine is rarely infested. Only the southern half of New Brunswick is infested, while all Nova Scotia and Prince Edward Island is infested. Severity of infestation seems directly associated with low-lying, poorly drained or water-logged soils. Two areas of heavier infestation and injury are apparent. One includes all of southeastern Maine east of the Penobscot River, with the greatest injury in the Princeton area, and from Bar Harbor north to Aurora. The other area extends from Augusta up the Kennebec Valley to Bingham. All of the infested part of Maine has been cut over more than once.

Unfavorable sites for growth of fir determine the endemic centers of infestation, and on these sites the balsam woolly aphid is always to be found. From these spots or areas it spreads out to attack injured or unthrifty trees. When favored by a series of mild winters, it builds up and attacks fir more generally. Low-lying areas of Washington and Hancock Counties have the heaviest infestations. Wherever drainage is so poor that sphagnum mosses and water-loving ferns thrive, the heaviest infestations occur. Trees standing a few feet away on higher ground are more resistant to attack. These areas of wet or water-logged soil often extend high up on hillsides. Some interior areas of the state have such heavy clay soil that fir growing on them is heavily attacked. Elsewhere trees are particularly subject to attack on the shallow ledgy soils of the coast and along roads, trails, or left in or bordering cuttings. Such trees are often killed while nearby trees in unopened stands are either not attacked or light infestations disappear without evident harm.

These local spots with the heaviest balsam woolly aphid attack are indicated by associated plants. On the undrained

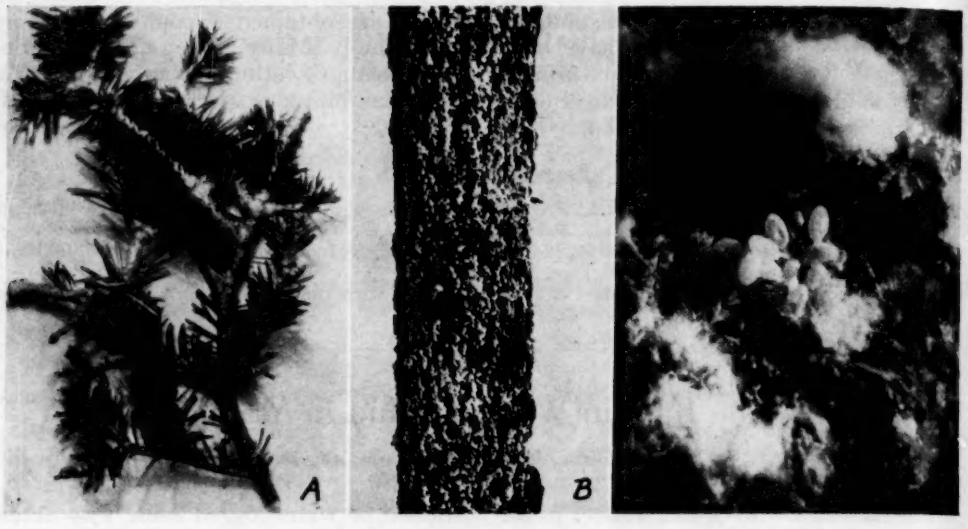

FIG. 1.—A. Swollen fir twigs following feeding. B. Heavily infested fir trunk. C. Waxy covering turned back to expose eggs on trunk.

areas the commonest plants are sphagnum and other mosses, water-tolerant grasses, gold-thread, and swamp dewberry in the depressions, while on the hummocks, mosses, ferns, *Dryopteris spinulosum*, *Osmunda*, etc., *Maianthemum*, bunchberry, *Pyrolas*, and club mosses are found with many others in lesser numbers. On wet and water-logged soils, grasses, sedges, and mosses are conspicuous, while some violets, *Pyrolas*, goldthread, ferns, mitreworts, and club mosses may occur. Growth of fir on these sites is slow. Measurements of the normal rate of diameter growth on trees, which later became heavily infested, gave an average of 0.18 of an inch per year. On the shallow ledgy soils of the coast and interior the plant growth is much more diverse and the same is true of the plant life associated with infested fir along roads, trails, and in cuttings. The most common plants on the well-drained plots are mosses, bunchberry, *Maianthemum*, aromatic wintergreen, wild sarasparilla, star flower, and brake.

Injury of two rather distinct types is produced by the balsam woolly aphid. One type is termed the "terminal phase," because the tips are injured and growth is more or less completely stopped. The other is called the "trunk phase," because the trunk is attacked. These two types of injury may possibly be due to different species; however, no morphological difference has been found and both types of injury seem always to be associated in Maine. Experiments gave proof that crawlers of the trunk phase will attack buds and vice versa. Small trees were heavily infested artificially with the trunk phase which heavily attacked buds and branches; conversely, crawlers from eggs of the tip phase settled on fir trunks in large numbers.

The terminal phase attacks the distal portion of the branches, extending back one or more years of growth. The bases of the buds and the enlarged nodes marking different years of growth are favored places for attack, with scattered individuals elsewhere. Some crawlers settle on the needles and feed on them. Terminal buds are killed or their growth arrested, ending all terminal growth. Attack by a considerable number of the aphid produces death of the part infested, while moderate numbers apparently cause the host to produce more or less gall-like swellings of the part attacked. Some trees exhibit greatly enlarged or gouty terminal portions, all of the twigs swollen with gall-like tips and nodes. This condition is often called "gout." This gouty or swollen condition becomes prominent the second year after attack. Death of the buds is often followed by dying and loss of needles on from a few inches to one to three feet of the top and tips. This results in a characteristic stag-headed appear-

ance. The terminal portions of injured trees appear swollen, stiff, and rigid, with many lateral twigs depressed. These stag-headed trees are especially noticeable in the small fir growing on shallow ledgy sites along the coast. Other trees which show little or no twig-dying cease to grow, often linger on for years until killed by suppression or otherwise. Trees with less injury develop other buds and may slowly recover, but such trees are readily killed by other insects. Very young trees may be quickly killed by an attack. The older trees are less subject to twig injury.

The trunk phase attacks all ages. Trees from one inch up have been seen with their trunks white with the insects, but the trees of pulp size and especially the older ones suffer most. On some local spots which have been under observation, trees rarely reach a diameter of ten inches before being killed. The trunk phase generally attacks the lower trunk, being heaviest below 12–15 feet; however, this is apparently due more to upward spread from below the snow line where the insect is able to survive subzero weather than to other causes. Extremely heavy infestations have been seen well toward the top of trees. The first insects tend to crowd into crevices, under bark scales and under moss. Infestations often build up to a stage where a large part of the trunk appears white.

Injury to the wood may be so severe as to render much of it unfit for lumber. This is due to formation of many thick-walled vessels and abnormal deposition of lignin. Two or three very thick rings may be formed following an attack. A reddish discoloration is so noticeable that it is often termed redwood. The abnormal lignin content makes the wood too brittle for good lumber; this and the discoloration lower its value for pulp. Balch & Hawboldt (1942, 1944) report a mortality of 50 per cent by volume on some plots and the rejection of a reported 35 per cent due to redwood in one cutting. Dead fir decays rapidly. Because of the amount of cull and the impossibility of floating pulp from dead trees or of storing the pulp, dead fir is completely lost on many operations.

Severe attacks are followed by reduced diameter growth. Measurements of the normal rate of diameter growth near the Waltham plot gave the following figures: 5 trees averaged 0.197 inches for 17 years; 10 trees averaged 0.248 inches for 13 years; and a third lot of 20 trees averaged 0.153 inches for 14 years. These measurements were made on trees which averaged about 9 inches at the end of the period. Despite the extremely thick rings which are formed by some trees for 2 to 3 years, the average rate of growth is greatly reduced. One set of 10 trees which was measured on their death showed a reduction of 26.3 per cent in growth during the last 4 years. Likewise, terminal injury results in reduction of diameter growth as well as the more or less complete cessation of terminal growth. Two sets of 10 trees at Bar Harbor were measured. One set had averaged 0.245 inches for 9 years, but after injury averaged but 0.1596 inches, or a reduction of 38.9 per cent; the other averaged 0.1835 for 8 years, dropping to 0.0925, or a loss of 49.6 per cent, both figures for losses being based on 5-year averages.

The group of insects to which the balsam woolly aphid belongs generally goes through a complicated life cycle with alternating hosts, reached by winged individuals. No winged individuals or males have been found in Maine, and balsam fir is the only native host. A large *Abies nordmanniana* at Bar Harbor was apparently killed by a heavy stem attack of this aphid in 1934. Other firs will doubtless be attacked as in the Old World. The biological data is based on studies at Bar Harbor, Mt. Desert Island, Maine, with other studies there and at the nearby interior (mainland) plot in Waltham. Two complete generations is the rule, May-June and August-September, and probably a partial third develops. Development of but one full generation has been reported elsewhere (many of the crawlers hatching in June and July and not continuing to develop), but in Maine, so far as is known, all of the crawlers hatching from the eggs produced in May and June develop. The insect is spread only in the crawler stage, which is the only stage with developed legs. The sedentary form of the first stage, which follows the active crawler, is the only stage known to overwinter. The crawler has a scanty fringe and dorsal row of wax plates which affords scanty winter protection. Stray second stage individuals were found in January and February. Active molting to the second stage was found from April 18

FIG. 2.—Three stag-headed fir trees, two small ones on the right, showing swollen trunk and branches.

on. Mature females were found ovipositing May 14, and they were abundant 10 days later and through June; nearly all died by July 5 to 20. Individuals molting into the second stage were found July 6. The first second-generation, ovipositing females were found July 15, and they soon became abundant, continuing so through August. The peak of the second generation passed by September 15 and crawlers were again abundant. There is ample time for a partial third generation in September and October but no definite proof of this. As late as October 18 a number of ovipositing females were found. The egg is smooth, glossy-yellow, elongate, about 0.192× 0.345 mm. The eggs are simply extruded from the body of the female and are found in and beneath the waxy threads. The incubation period ranges from 7 to 14 days, avergaing about 9.33 days for the summer brood. The insect molts three times. The mature female is somewhat less than 0.5 millimeter in length, a blackish, sack-like being with stylets much longer than its body inserted into the bark. When it reaches maturity a copious covering of fine, white, waxy threads covers it which gradually discolors. The spring generation of females apparently lays more than one hundred eggs each, the highest recorded being 149. The later broods produce a much smaller number. Some crawlers settle on the needles and feed on them. The crawler stage lasts about 6 days.

Little is known of how this insect spreads, though the assumption is that wind, birds, insects and animals aid in its dispersal. Experiments demonstrated that both the crawlers, which hatch from the eggs and distribute the insect over the tree, and the eggs in the cottony covering, are wind-carried. Three tanglefoot trapsheets set up 5 to 6 feet above the ground and 5 to 6 feet from a heavily infested tree caught five crawlers and two eggs. A second experiment was similar but used tanglefoot only 3 feet high. This caught two crawlers. Two sheets of tanglefoot placed flat on the ground half way to the tips of branches caught 30 crawlers and 8 eggs.

Infestations range from a few to many hundred individuals per square inch. In bark crevices and other protected spots the first-comers settle down, the mature insect producing up to a hundred eggs. Part of the young remain under the waxy protection produced by the parent and the clusters increase in numbers, most little masses of waxy threads covering many individuals.

When but one or two of the waxy masses is present per square inch the infestation is termed "light," when several are present it is a "medium" infestation, and when the trunk is dotted with them, the term "heavy" is used.

The presence of a few masses of the insect on the trunk is of little importance as these come and go, and the infestation may build up to a medium stage without any evident injury; however, this is a critical point in the infestation when injurious physiological disturbances will be felt by the tree. Unless checked by climatic conditions, once the insect reaches an infestation of medium to heavy it increases rapidly and the tree is dead in a few years. Annual records on numbered trees show that of those where the infes-

tation reached a stage recorded as medium, only 30.3 per cent survived, and when heavy stage was reached but 16.7 per cent survived. Trees which have died have died on an average in 3.15 years after the infestation reached the medium stage, while a heavy infestation resulted in death in 2.51 years.

These figures show a survival of 16.7 per cent of the trees with a heavy infestation and these trees are resistant to further attack. The author believes that many of these had the benefit of killing cold as the critical infestation was being reached. The trees respond with a thickened, rough, often somewhat checked and pitchy bark which largely prohibits further attack by the insect. Light infestations may persist on some of these trees or they may become lightly to moderately infested, but they are generally nearly immune to attack. They are often killed by bark beetles and round-headed borers following injury by the balsam woolly aphid.

Natural control is chiefly by low temperatures. Somewhere from 15 to 30° F. below zero killing temperatures are reached, and severe winters may kill all above the snow line. Since the bases of the trees are less favorable, this may result in nearly complete kill. The bad outbreak in the early thirties was apparently stopped by the severe winter of 1933–1934. Actual counts on the same tree, made in the fall (because of the large number of dead present) and in the spring, have shown winter kills ranging from zero up to 90 or 100 per cent. Observation of the heavily infested trees has shown that winter kill may be more or less complete above the protecting snow and that reinfestation of the trunk spreads upward from the base, and since but low numbers are normally found on the base this greatly reduces the insect.

Predators and parasites are of small importance in Maine. Occasionally syrphid fly larvae are found feeding on the aphid. In Indian Town, Maine, in August 1946, a dozen larvae of the harvester, *Feniseca*

Table 1.—Control of woolly aphid from spraying.

Spray	Dilution	Date Applied	Stage of Insect	No.	Per Cent Kill
Nicotine sulphate+*Penetrol* 0.5	1–400	VI-15	Larvae	998	96.8
	1–400	V-30	Females	262	69.4
	1–400	VIII- 1	Females	274	98.5
	1–400	VII- 9	1st & 2nd	1628	67.6
	1–400	VII- 9	1st & 2nd	1652	67.0
	1–400	VII-16	1st & 2nd	1130	94.5
	1–600	VI-15	Larvae	1044	90.0
	1–600	VII- 9	1st & 2nd	1407	66.5
	1–600	VII- 9	1st & 2nd	1410	67.0
	1–600	VII-16	1st & 2nd	317	89.1
	1–800	VI-15	Larvae	1058	36.9
	1–800	V-30	Females	590	56.8
	1–800	VIII- 1	Females	300	65.7
	1–800	VIII-21	Eggs & larvae	1002	66.1
	1–1,000	VI-15	Larvae	703	78.9
	1–1,000	VIII-21	Eggs & larvae	1309	42.1
Nicotine sulphate+*Sunoco Oil* (1–50)	1–600	VII- 9	1st & 2nd	1037	92.8
	1–600	VII- 9	1st & 2nd	1047	92.1
Sunoco Oil	1–11	IV-28	1st & 2nd	—	100.0
	1–25	IV-29	1st & 2nd	310	98.3
	1–30	IV-29	1st & 2nd	512	92.0
	1–35	IV-29	1st & 2nd	226	93.4
Lethane+*Lethane Spreader* 1–400	1–400	VIII- 1	Females	359	77.6
Lime sulphur	1- 8	IV-28	1st & 2nd	—	100.0
	1–12	IV-28	1st & 2nd	—	100.0

targuinus (F.), were found feeding on the aphid. Mr. H. W. Capps, Division of Insect Identification, U.S.D.A., confirmed this identification and informed me that this is their first record of this predator on the balsam woolly aphid. Although it feeds commonly on the rather similar beech scale, the twice-stabbed lady-beetle *Chilocoris stigma* (Say) has never been found feeding on this aphid. In the Maritime Provinces an introduced fly larva, *Leucopis obscura*, is of considerable importance (Balch 1941). Parasites are rare or absent. None have been secured from the material isolated for that purpose.

Control measures have received limited attention because fir has been a low value forest tree. In this project, Peirson & Gillespie (1934) carried out preliminary checks on some sprays, followed by spray tests in 1933 to 1935 to determine a successful spray for ornamental and other fir. Most experiments consisted of one application (sometimes two were applied and results added together) of 5 gallons of the the spray to two or more trees. The spraying was done with a hand-operated sprayer. Checks were taken from the same or similar nearby trees. A considerable percentage of dead insects was regularly present and all spray results have been corrected for percentage of kill. The waxy covering evidently provides considerable protection against spray penetration and the kill of mature insects and eggs was always much lower than that of less protected stages. The addition of a suitable wetting or caustic agent to most sprays needs investigation. Extensive spraying work on the similar beech scale has shown that caustic sprays like lime sulphur applied with force are required for good kill. In these experiments the stronger concentrations of *Sunoco Oil* caused light to severe burning. Both salvage and destruction of heavily infested trees have been recommended. Experiments by Gillespie on effect of cutting such trees and on dispersal of the crawler stage indicated destruction is unnecessary.

RECOMMENDATIONS FOR CONTROL.—Lime sulphur at dormant strengths (1 to 8 and 1 to 12) has given 100 per cent kill, and judging from its effectiveness against beech scale, 1 to 19, or 5 gallons with 95 gallons of water (20 pounds of powder), applied thoroughly with force, will give 100 per cent kill. Stronger concentrations of oils are effective but must be carefully selected and used to prevent serious burning. MacAloney (1940) recommends oil at 1 part to 25 parts of water, and this dilution should be safe with an oil suitable for evergreens. Nicotine sulphate, 1 to 400, has given good results, and this may be easily and safely applied at any time. Sprays will be most effective when directed against the crawler stage because of the scanty waxy protection present at this stage of growth—6-18-47.

LITERATURE CITED

Annand, P. N. 1928. A contribution toward a monograph of the *Adelginae* (*Phylloxeridae*) of North America. Stanford Univ. Pubs., Univ. Ser., Biol. Sci. **6**(1): 1–146.

Balch, R. E. 1936. The balsam woolly aphid (*Adelges piceae* Ratz.). Canada Dept. Agr. Ent. Branch Div. Forest Ins., Spec. Circ.

Balch, R. E. 1931–1941. Balsam bark louse (*Dreyfusia piceae* Ratz.). Report Dept. Lands and Forests of Nova Scotia: 1931, pp. 48–50; 1936, pp. 43–44; 1940, pp. 36–37; and 1941, p. 36.

Balch, R. E., and L. S. Hawboldt. 1942, 1944. Balsam bark louse (*Dreyfusia piceae* Ratz.). Report Dept. Lands and Forests of Nova Scotia for: 1942, p. 51; and 1944, p. 40.

Kotinsky, J. 1916. The European fir trunk bark louse (*Chermes* (*Dreyfusia*) *piceae* Ratz.) apparently long established in the United States. Proc. Ent. Soc. Wash. **18**: 14–6.

MacAloney, H. J. 1940. Fir bark louse. *In* Important Tree Pests of the Northeast. Mass. Forest and Park Assn. pp. 96–9.

Peirson, H. B. and A. M. Gillepsie. 1934. Some observations on the balsam woolly aphid in Maine. JOUR. ECON. ENT. **27**: 340–1.

Mr. R. E. Hamman, who has recently received his Master's Degree in Entomology from the University of Illinois, has accepted a position on the Technical Sales and Development staff of Julius Hyman & Company, Denver, Colorado.

The Saratoga Spittlebug

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In recent years the Saratoga spittlebug, *Aphrophora saratogensis* (Fitch), has caused considerable injury to both jack pine, *Pinus banksiana* Lamb., and red pine, *P. resinosa* Ait., plantations of sapling size in many parts of the Lake States region (Secrest (1944), Anderson (1947). In some places naturally established open-grown stands have also been injured. During 1944 a study of the mycological pathology of the problem was undertaken by others while the writer studied the entomological aspects, the biological facts of which are considered in the present paper. For an account of another common pine-infesting species, the pine spittlebug

FIG. 1.—Adult spittle insects in feeding position on a jack pine twig.

A. parallela (Say), see that presented by Speers (1941).

INSECT CHARACTERISTICS.—*Aphrophora saratogensis* adults are tan or light-brown insects 8 to 10 mm. long. The average length of 30 males measured was 8.7 mm. (range 8.0 to 9.1 mm.), whereas of a like number of females the average was 9.6 mm. (range 9.0 to 10.0 mm.). A light irregular stripe, slightly elevated and frequently broadening posteriorly, is usually present along with the dorsal median line of the head and pronotum, as can be seen on 2 of the insects in figure 1. This line was absent on 9 individuals and indistinct on 24 others out of 300 adults checked. The hemelytra are about three times longer than broad, and are varied with light mottling which frequently forms 2 wavy transverse bands on each. The band closer to the scutellum, together with a

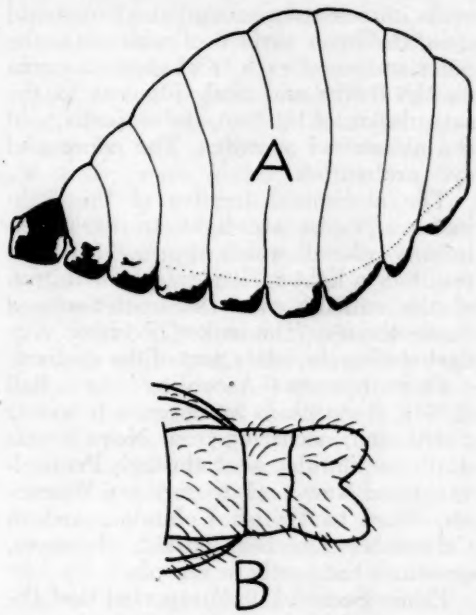

FIG. 2.—(A) Abdomen of a second-instar nymph showing markings on the pleural lobes. (B) Genital plates of an adult male.

third band extending caudad from near the humeral angle, form a subequal diamond-shaped pattern, when both fore wings are in a normal resting position and are viewed dorsally. The intensity of the mottling varies considerably, however, so that probably the most constant characteristic is the shape of the male genital plates. A figure of these, together with those for all the other known North American *Aphrophora* species, is presented by Doering (1941). An original drawing of

[1] This paper contains the results of a cooperative study by the following agencies: The Bureau of Entomology and Plant Quarantine, the Bureau of Plant Industry, Soils, and Agricultural Engineering, and the Forest Service, all in the U. S. Department of Agriculture; the Department of Economic Entomology and the Department of Plant Pathology of the University of Wisconsin; and the Wisconsin Conservation Commission. The writer acknowledges the aid received from many individuals in these organizations.

the male genital plates of *A. saratogensis* is also presented in figure 2, B.

The nymphs are from about 2 mm. (first instar) to 8 mm. (fifth instar) in length. A scarlet abdomen is the most striking characteristic of the first four instars. Only the terminal abdominal tergite and the pleural lobes are dark in color, as shown in figure 2, A. This melanistic pigmentation of the latter is practically absent on first-instar nymphs, but then increases with each succeeding instar through the fourth. The head, thorax (except sternites), and legs are also dark gray to black. Immediately following ecdysis, however, the melanistic pigmentation is absent for a short period; hence the parts usually dark are then light. The median line on the head and thorax is light, as are also the areas immediately around the compound eyes, the inner surface of each coxa, the outer surface of each trochanter, the area on the femur and tibia adjacent to the articulation of the two, the empodia, and the abdominal sternites. The compound eyes are scarlet.

The abdominal tergites of the fifth-instar nymphs are light to dark mahogany-colored, which appears to be the result of a light melanistic pigmentation of the cuticula over the scarlet-colored inner tissues. The color becomes very dark during the latter part of the stadium.

DISTRIBUTION.—According to Ball (1934), *Aphrophora saratogensis* is widely distributed, occurring from Nova Scotia south to Florida, west through Pennsylvania and New York to northern Wisconsin, there to British Columbia, and in California. Doering (1941), however, questions the southern records.

EGG.—Secrest (1944) reported that the eggs were laid in shallow slits or under scales of bark of sweetfern, *Comptonia peregrina* (L.) Coulter. The writer was unsuccessful in observing this. In 1946, on the other hand, H. E. Milliron of the Bureau of Entomology and Plant Quarantine found that the eggs were commonly laid in the sheaths of the current season's needles of jack and red pine and also under bud scales of several species of hardwoods and red pine. The jack pine buds were too resinous to be attractive.

Eggs removed from gravid females in 1944 were smooth, light in color, about 0.6 mm. in diameter and 1.8 mm. long; one end was rather pointed, and the long axis slightly curved. The first fully developed eggs were removed from females collected on July 24, which was just 5 days after the first copulating pair had been observed. From 105 females collected during August the average number of eggs removed was 9.7 (range 0 to 27).

NYMPHAL DEVELOPMENT.—In 1944 the first nymphs were found on May 17, when the leaf buds were expanding on sweetfern and blueberry. From this time on, the periods, and daily maximum and minimum temperature averages in °F., during which half or more of the insects were in each of the instars, were as follows: First instar, May 17 to 27 (72.6°, 44.5°); second instar, May 28 to June 1 (86.8°, 51.8°); third instar, June 2 to 11 (71.4°, 43.6°); fourth instar, June 12 to 20 (76.9°, 52.9°); fifth instar, June 21 to July 4 (82.4°, 50.3°). In all about 3700 nymphs were observed. The temperatures were obtained by means of a thermograph which was located only a few inches above the ground surface in a shelter. In 1945, however, nymphal development was two weeks later than that given above.

The length of the nymphs was rather variable, depending on the degree to which the abdomen was extended. Nevertheless, for 10 alcohol preserved nymphs measured for each of the respective instars the average lengths (figures in millimeters, ranges in parentheses) were as follows: first, 2.0 (1.7–2.1); second, 3.0 (2.8–3.5); third, 4.3 (3.7–5.0); fourth, 5.8 (5.4–6.5); and fifth, 7.5 (6.6–8.1). Head capsule widths measured just in front of the antennae were as follows: first instar, 0.4 mm.; second instar, 0.6 mm.; third instar 0.8 mm.; fourth instar, 1.0 mm.; and fifth instar, 1.3 mm. Ten nymphs were observed for each instar and little variation was noted between individuals of the same instar.

Another useful characteristic for recognizing the different instars was the amount of black pigmentation on the pleural lobes. The caudal (IX) tergite, including the pleural lobes, was gray on the tiny first-instar nymphs. In the second instar the pleural lobes of the eighth abdominal segment were also almost completely black, with the dark portion extending slightly dorsad in the central part of the lobes, as shown in figure 2, A. The remaining lobes were black on the cephalic and ventral margins,

the color decreasing in amount on each successive segment progressing cephalad. The lobes of the seventh segment approached the darkness of that of the eighth, but lacked the median dorsal extension. In the following two instars the extent of melanin pigmentation of the pleural lobes increased still more. The pleural lobes of the seventh abdominal segments for the third instar and those of one or more additional segments for the fourth instar were almost completely black with the characteristic dorsal extension. The distinguishing color characteristics for the fifth instar have already been given under Insect Characteristics.

Table 1.—Hosts of *Aphrophora saratogensis* nymphs.

Host Plants[1]	Stems Observed	Fifth-Instar Nymphs per Stem
	Number	*Number*
Salix humilis Marsh.	14	7.9
Comptonia peregrina (L.) Coulter	340	5.0
Rubus spp.	20	2.3
Epilobium angustifolium L.	11	2.1
Fragaria virginiana Duchesne	20	1.0
Pteridium aquilinum (L.) Kuhn.	60	0.7
Hieracium aurantiacum L.	22	.7
Populus tremuloides Michx.	30	.7
Achillea lanulosa Nutt.	20	.7
Comandra umbellata (L.) Nutt.	10	.6
Erigeron ramosus (Walt.) BSP	32	.3
Solidago juncea Ait. and *S. nemoralis* Ait.	40	.3
Convolvulus spithamaeus L.	30	.2
Vaccinium canadense Kalm.	100	.2
Lactuca canadensis L.	20	.2
Senecio plattensis Nutt.	23	.2
Aster lindleyanus T. and G. and *A. macrophyllus* L.	60	.1
Waldsteinia fragarioides (Michx.) Tratt.	10	.1
Diervilla lonicera Mill.	100	.1
Antennaria canadensis Greene	80	.1
Gaultheria procumbens L.	30	0[2]
Anemone quinquefolia L.	5	0[2]
Anaphalis margaritacea (L.) B. and H.	—	—[2]
Pedicularis canadensis L.	—	—[2]

[1] N. C. Fassett, curator of the herbarium at the University of Wisconsin, kindly checked the identification of the plants.
[2] Nymphs in earlier instars found on these hosts.

Hosts.—In Florida, Ball (1928) found that *Aphrophora saratogensis* nymphs had a different host, *Woodwardia virginica* (L.) Smith, than the pine-feeding adults. The same year Pladidas & Smith (1928) listed the nymphs as being a pest of strawberries in Louisiana. In the North, Secrest (1944) found that sweetfern was the principal nymphal host. He also reported finding a few nymphs on a sprout of *Populus grandidentata* Michx. During the 1944 season in northern Wisconsin the writer found that nymphs of all instars formed their spittle masses on many other species of plants (Table 1). Of those most favored, sweetfern was the most abundant in the area studied, averaging 8.4 ± 1.41 stems per quarter milacre for the 20 plots sampled. For *Rubus* and *Salix* there were 0.6 ± 0.17 and $0.15 \pm .15$ stems per quarter milacre, respectively.

In 1946 H. E. Milliron and the writer noted a few nymphs spittled on the following additional hosts: *Taraxacum officinale* Weber, *Lysimachia quadrifolia* L., *Oenothera biennis* L., *Corylus cornuta* Marsh., *Rosa blanda* Ait., *Lonicera canadensis* Marsh., *Castilleja coccinea* (L.) Spreng., *Verbascum thapsus* L., *Anemone canadensis* L., and *Trifolium repens* L. None of these were highly favored by the nymphs.

The nymphs formed their spittle masses and fed in the vicinity of the root collars on the host plants, where they usually remained concealed beneath the surface of the litter. When the nymphs were extremely abundant, however, the spittle masses became very large and extended above the surface of the litter during the last stadium, as shown in figure 3.

During the developmental period the nymphal density decreased considerably on most of the host plants, whereas for sweetfern the opposite occurred. On 9 of the most common herbs, plus the shrubs *Vaccinium* and *Diervilla*, the number of nymphs per stem decreased from 1.5 ± 0.25 for 602 stems observed to 0.2 ± 0.05 for 470 stems for the first and fifth instars respectively, whereas for sweetfern nymphal concentration increased from 0.3 ± 0.11 for 149 stems observed to 5.0 ± 0.43 for 340 stems for the first and last respective instars. The writer suspects that the concentration of nymphs also increased on *Salix*, *Rubus*, *Pteridium*, and possibly on a few other species. Apparently some of the nymphs left their original hosts and migrated to the more favored species. During the fifth stadium, when the change of hosts was most pronounced, 105 nymphs were released on

one side of a cage which covered an area of 1 square foot. After three days 78 of the nymphs had moved to the opposite side of the cage and were spittled on the sweetfern shoots located there, 15 were on an aspen shoot, and 7 were on the *Antennaria*, which was abundant over the whole area. The results indicate that it is possible for the nymphs—at least those in the fifth instar—to crawl through or over the litter and plants to find the more favored hosts.

FIG. 3.—Spittle mass at the base of a sweet fern stem.

Rearing of nymphs (starting with the first instar) was successful on *Lactuca* and *Waldsteinia* and unsuccessful on *Solidago*, *Senecio*, *Aster*, *Antennaria*, and *Anemone*. From late fourth-instar nymphs, adults were reared on *Salix*, *Comptonia*, *Rubus*, *Pteridium*, *Hieracium*, *Comandra*, *Solidago*, *Lactuca*, *Waldsteinia*, and *Diervilla;* whereas the fourth-instar nymphs died on *Fragaria*, *Vaccinium*, *Senecio*, *Aster*, and *Anemone*. An attempt to rear adults from third-instar numphs on *Diervilla* was unsuccessful, but successful on *Comptonia*.

During the first stadium, large numbers of nymphs were found concentrated on individual plants. On 1 *Lactuca* plant 51 nymphs were counted and on another 40, while 30 and 25 first-instar nymphs were collected from 2 *Aster* plants. When 2 or more nymphs were on 1 plant or stem, they usually all inhabited the same spittle mass.

Although the nymphs did not feed on pines (the hosts of adults), they were found to be concentrated in the vicinity of both red and jack pines. Sixty to 100 feet from the edge of an 8-year-old plantation the spittle masses were only 7.7 $\pm$3.0 per cent as abundant as they were within the stand. Over 600 sweetfern stems were examined in five different locations in obtaining these data. Likewise, large decreases in the spittle mass concentration was observed as the distance increased from single isolated larger jack and red pines of 3- to 16-inch trunk diameter.

Red pine was the most favored host for the adults of *Aphrophora saratogensis*, with jack pine in second position. For 10 closely adjacent pairs of trees of these 2 species, the averages were 5.5 and 1.9 feeding punctures per square centimeter of inner bark for the red and jack pine, respectively. The difference was highly significant ($t=6.00$). Comparable data for white pine, *Pinus strobus* L., were not obtained, because this species was seldom encountered in the plantations of the two-needled pines. Nevertheless, a few indirect observations were made by determining the nymphal population present beneath 5 pairs of adjacent (50 to 100 feet apart) large red and white pines. The sweetfern beneath the red pine was infested with 3.5 ± 0.85 nymphs per stem (50 stems examined) as compared with 0.5 ± 0.12 nymphs per stem (75 stems examined) beneath the white pine. Thus, the feeding punctures on red pine were about

three times greater than on jack pine, and the nymphs counted beneath large trees were about seven times greater than beneath white pines.

Fitch (1851) reported that adults were common on pitch pine, *Pinus rigida* Mill. (?), and sometimes occurred on white pine. A few adults were also observed feeding on the latter host by the present writer.

ADULT ACTIVITY.—In 1944 the first adult was observed on July 2. During the following week approximately 88 per cent of the emergence occurred, with the remaining 12 per cent of the individuals maturing during the following three weeks. In 1945 the first adult was observed on July 17.

Of the 3106 adults in 18 collections, 45.8 per cent were females.

When feeding on pine twigs, the insects would usually take positions down among the needles, facing in the direction the needles sloped, *i.e.*, toward the tips. Then, if they were disturbed, they could easily slip out through the needles when leaping from the twigs.

CLIMATIC AND BIOLOGIC CONTROLS.—A natural control factor which may operate during the spring after the nymphs have become active is low temperature. A few observations made by the writer (Table 2) supplement those made by Secrest (1944). Secrist used fifth-instar nymphs, whereas the writer used third-instar insects. In the present work a pint vacuum bottle was adapted for the freezing chamber, into which the salt-ice freezing mixture was placed. The nymphs, spittled up on a portion of the host plant, were placed in a 20-ml. vial, which was then lowered into the freezing mixture. The temperature drop was recorded with a liquid (alcohol) thermometer. The bulb was placed adjacent to the insect, with the stem extending to the outside through cork stoppers so that temperature readings could be made from without. Third-instar nymphs tested were found to be susceptible to momentary exposures of temperatures in the twenties (Table 2). Preconditioning the nymphs at 32° F. for 12 hours reduced the mortality somewhat, but did not lower the minimum at which 100 per cent mortality occurred.

Table 2.—**Mortality of third-instar nymphs of *Aphrophora saratogensis* following momentary exposure to cold.**

TEMPERATURE	INSECTS TESTED	MORTALITY
° *F.*	*Number*	*Per Cent*
32	10	0
30	21	38
28	12	50
25	14	62
23	12	75
20	13	100

The young nymphs in their natural habitat were well protected by the litter, so that the minimum temperatures which occurred there were considerably higher than the air temperatures a few inches above. During 7 nights when the air temperature 3 inches above the surface of the litter in a weather shelter descended into the twenties or thirties, the minimum temperatures beneath the litter averaged 8.6° F. higher. On the day previous to one of these nights when a frost had occurred, 30 of the third-instar nymphs were caged on 6 plants (5 nymphs on each) above the litter, with 30 others caged similarly but covered with litter, for a check. That night the air temperature descended to 27.5° and remained below 32° for 7 hours (the exposure to cold was longer than in the individual tests described above) as compared with a minimum of 34° beneath the litter. Mortality was 80 per cent for the nymphs not protected, whereas no mortality occurred among the nymphs protected by the litter. On the basis of these data it follows that very severe freezes during the period of nymphal development would be required to substantially reduce the insect population.

Biological agencies did not appear to be very active in reducing the spittle insect population. A few dead mummified nymphs were collected, which suggested fungus activity; parasite larvae were removed from the abdomens of 3 out of a total of 220 adults dissected; and 1 spider was observed feeding on an adult.

CONTROL.—Preliminary tests with insecticides (Anderson 1945) indicated that direct control of the spittle insect adult might be possible; consequently, tests with airplane applications of DDT are being conducted. For coordinating this spraying work in 1945 and 1946 the phenological data plus the data on the characteristics of the different instars

were found useful for predicting when the adults would emerge.

The nymphal host data are likewise of practical significance in that they suggest means whereby the plantations might be managed so that growth conditions would be made unfavorable for the nymphal host plants. Secrest (1944) suggests the encouragement of desirable hardwoods to develop mixed stand which help to crowd out the sweetfern and other nymphal host plants. A few data collected on this relation of mixed stands with the hardwoods overtopping the pine, to the amount of injury (Table 3), support Secrest's observations. *Populus tremuloides* Michx., *Betula papyrifera* Marsh., and *Acer rubrum* L. were the principal hardwoods encountered.

Table 3.—Comparison of mixed and nearby pure stands as to tree density and injury on 6 paired plots.

Total Trees per Acre	Pine		Hardwoods		Trees One-Fourth or More Dead
	Per acre	Ave. height	Per acre	Ave. d.b.h.	
Number	*Number*	*Feet*	*Number*	*Inches*	*Per Cent*
2,410	960	4	1,450	2	13
860	820	6	40	2	78
	Difference for odds of 19 to 1				
635	472	—	—	—	80

Paired plots were used for each observation, the sites being similar for both plots of each pair and in no case separated by a distance of more than 75 feet. Plot size was either 0.01 or 0.02 acre. Three of the paired plots were red pine, and the remaining two were jack pine. Both species of pine growing under the hardwoods were spindly and growing poorly, which conditions probably aided in making these trees less attractive to the insects.

Denser stands of the pine would also help to retard the plants growing beneath and, in addition, would provide more food for the adult spittle insects, thereby lessening the feeding on each tree. The greater the quantity of adult food in relation to the quantity of nymphal food the less severe would be the tree injury. Examination of four pairs of plots indicates that the denser groups of pine actually had much less injury as the data in table 4 show.

The sites were similar for both plots of each pair and in no case were the plots separated by a distance of more than 75 feet. Plot size was 0.02 acre.

These observations do not imply that small groups of either densely stocked pine or mixed pine-hardwood will remain uninjured. When the food is depleted in the adjacent poorly stocked areas, the insects move to the better source of food in the uninjured denser groups. The denser stands would have to be of sufficient size to remain immune.

In a 3-acre area intensively studied in 1944 the jack pine averaged 845 trees per acre distributed according to height as follows: 2 to 4 feet, 3 per cent; 4 to 6 feet, 21 per cent; 6 to 8 feet, 49 per cent; 8 to 10 feet, 18 per cent; and 10 to 12 feet, 9

Table 4.—Relation of density of stocking and size of jack pine to occurrence of injury on 4 paired plots.

Trees per Acre	Average Height of Trees	Trees One-Fourth or More Dead
Number	*Feet*	*Per Cent*
781	6	78
1,237	10	2
Difference for odds of 19 to 1		
406	2	34

per cent. The spittle insect population, based on counts made during the last nymphal instar, was 352 insects per tree. A total of 831 stems of the 14 most important nymphal host plants were examined to determine nymphal concentration, and 20 quarter-mil-acre plots were observed to determine the nymphal host-plant density. The 352 spittle insects per tree killed an average of 52 lineal feet of twigs and branches which was 32 ± 5 per cent of the total lineal length of branches and twigs per tree. Had there been twice as many trees of the same size per acre on which the insect feeding could have been distributed, an insect population of the same size would have caused no serious killing. Planting more densely than the usual 1200 trees per acre may be too costly yet Eyre & LeBarron (1944) state that one pulp and paper company carrying on a fair-sized reforestation program plant 1700 to 2700 trees per acre.

Destruction of the nymphal host plants with one of the newer plant killing chemicals such as 2,4-D is another possible method for control of this spittle insect. Whether the nymphal host plants are sufficiently susceptible and the pines re-

sistant to such chemicals remains to be determined.

It is emphasized that the observations presented here were limited and merely suggest possibilities which should be investigated further.

SUMMARY.—*Aphrophora saratogensis* (Fitch) adults are light brown or tan insects 8 to 10 mm. in length, with mottled hemelytra about three times longer than broad. The eggs are laid in needle sheaths of pines and in buds of several species of hardwoods and red pine. The young nymphs are found in early spring at the time of the leaf buds of sweetfern and blueberry are breaking (mid May in northern Wisconsin) and development is complete about 7 weeks later. The abdomens are scarlet until the final instar at which time they become dark mahogany-colored. The nymphs were found spittled on a total of 36 species of herbaceous and low-growing woody plants. First-instar nymphs were most abundant on the herbaceous plants, but as they became older they moved to more favored woody plants, including prairie willow, sweetfern, and species of *Rubus*. The nymphs were found to be susceptible to very hard freezes.

The adults feed chiefly on the needle-bearing twigs and branches of jack and red pine and when abundant cause severe injury to the trees. The fact that the adults feed on different types of host plants than do the nymphs indicates that if the ratio of the amount of adult food to the amount of nymphal food be increased sufficiently the killing injury to the pine would be eliminated; therefore, denser plantings of the pine should be considered. Volunteer species of hardwood should also be encouraged to the extent that the plantations be completely stocked, thereby aiding to subdue the undergrowth nymphal host plants; however, whether the hardwoods should be allowed to overtop the pine is questionable because both red and jack pine are intolerant of overhead shade.

LITERATURE CITED

Anderson, R. F. 1945. DDT and other insecticides to control the Saratoga spittle insect on jack pine JOUR. ECON. ENT. 38(5): 564–6.

Anderson, R. F. 1947. Saratoga spittlebug injury to pine. JOUR. ECON. ENT. 40(1): 26–33.

Ball, E. D. 1928. Notes on the Cercopidae of America, north of Mexico (Homoptera). Ent. News 39(2): 47–9.

Ball, E. D. 1934. The spittle insects of the genus *Aphrophora* occurring in the United States (Homoptera: Cercopidae). Ent. News 45(7): 175–9.

Doering, K. C. 1941. A revision of two genera of North American Cercopidae (Homoptera). Kan. Ent. Soc. Jour. 14(3, 4): 102–34.

Eyre, F. H., and R. K. LeBarron. 1944. Management of jack pine stands in the Lake States. U. S. Dept. Agr. Tech. Bul. 863.

Fitch, A. 1851. Catalogue of the known Homoptera of the State of New York in 1851. Report of Regents of University of State of New York on State Cabinet of Natural History. Reprinted in New York State Entomologist Report 1892, 385–413.

Plakidas, A. K., and C. E. Smith. 1928. Diseases and insect pests of the strawberry in Louisiana. La. State Univ., Agr. and Mech. Col. Ext. Circ. 113.

Secrest, H. C. 1944. Damage to red pine and jack pine in the Lake States by the Saratoga spittle bug. JOUR. ECON. ENT. 37(3): 447–8.

Speers, C. F. 1941. The pine spittle bug (*Aphrophora parallela* Say). N. Y. State Coll. Forestry, Syracuse Univ., Tech. Bul. 54.

The United States Department of Agriculture has instituted the practice of giving Department "Honor Awards" to its employees for various classes of meritorious service. The first presentation of awards under this plan took place on November 12, 1947 but the regular date in the future will be some time in May of each year.

Among those receiving awards this year were Sievert A. Rohwer, who received a Superior Service award, and Fred C. Bishopp and Ernest R. Sasscer whose awards were in recognition of continuous service through a period of 40 years or longer.

A Parasitic *Aspergillus* on Mealybugs[1]

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The following investigation, although completed some time ago, has been reported only in brief abstract form (Boyce & Fawcett 1928; Fawcett 1944). A more detailed account of the work is presented here because of its possible economic value in entomological work, as well as because of its scientific interest.

In the spring of 1926, in southern California, during a period when relatively high humidity prevailed out of doors, mealybugs that were being propagated in insectaries died in large numbers. This mortality was coincident with the appearance on the dead insects of a fungus later identified as belonging to the *Aspergillus flavus-oryze* group, as defined by Thom and Raper (1945), and closely related to one of the members of this group, *A. parasiticus*, as described by Speare (1912). Since this condition in the insectaries was of short duration and ceased with the advent of drier atmospheric conditions, it was not then considered serious. When similar condition arose the following spring, however, the insectary superintendents pointed out the importance of an investigation.

Mealybugs were being propagated on potato sprouts in the insectaries in large numbers to be used as hosts in the rearing of millions of parasitic larvae of ladybird beetles, *Cryptolaemus montrouzieri* Muls., which were being liberated in citrus groves each year to prey upon the mealybugs infesting the trees (Smith & Armitage 1931). It was quite evident that a serious loss would result should a disease of mealybugs get a footing in the insectaries, particularly when weather conditions outside were such that it would be difficult to maintain optimum indoor conditions. A serious study of the problem was therefore begun early in 1928 at this Station.

Cultural Work with the Fungus.—Pure cultures of the fungus were obtained on poured plates of glucose potato agar, using inoculum from specimens of mealybugs which had been sent in from one of the insectaries. Corn-meal agar was also used, but on this the fungus grew less rapidly than on glucose potato agar. Growth took place within a wide range of temperatures. In one series of experiments described later, the fungus grew well in temperatures ranging from 17° to 32° C. The perfect stage was not observed.

Tests of the Parasitism of the Fungus.—Although general observations in insectaries where the fungus occurred had indicated that the mealybugs were dying as a direct result of a fungal attack, convincing proof that the fungus was parasitic was lacking. To determine this point, two species of mealybugs, *Pseudococcus gahani* Green and *Phenacoccus gossypii* T. & C., were propagated on potato sprouts and inoculated with spores from pure cultures.

In preliminary tests the mealybugs were placed in petri dishes, on filter paper which had been moistened with sugar solution. Spores were dusted on the mealybugs with a camels-hair brush. When inoculated in this manner, however, only small numbers of mealybugs became infected and died. Another disadvantage was that other fungi grew very profusely on the moistened filter paper.

A more satisfactory method of inoculation was that of putting mealybugs into 2-day-old pure cultures of the fungus in poured plates of glucose potato agar. Adequate inoculation was insured by rolling the insects over several times in the culture with a camel's-hair brush.

Checks were set up and run parallel with each series of inoculations. For each check, glucose potato agar was poured into sterile petri dishes into which mealybugs were placed after the media had cooled and hardened. In later trials to show that the mealybug mortality could not be attributed to a smothering effect of the fungus, apart from parasitism, a yellowish-brown saprophytic form of the group *Aspergillus flavus-oryzae*, which grew at much the same rate and with about the same degree of sporulation as

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the parasitic form, was used in the checks. Survival of insects placed in such cultures and rolled in the spores was similar to that of the insects placed on the sterile medium.

All petri dishes were placed in a controlled temperature chamber maintained at a fairly constant temperature of 32° C., with a relatively high humidity. The cultures were examined daily in an inoculation chamber where they could be opened up for minute inspection and the numbers of dead insects recorded. At this temperature, from 95 to 100 per cent of the mealybugs were killed within 48 hours after inoculation, while practically all of those in the check dishes were still in normal condition. Most of the insects were killed before the fungus sporulated, but a few live mealybugs were observed to have several sporophores developed on their bodies. These particular insects died within 12 hours after this observation, and many sporophores were in evidence very shortly thereafter.

Infected mealybugs were sluggish when irritated with a camel's-hair brush, and had a swollen appearance. A glistening drop of excretion on the dorsum of the abdomen was noted to be quite characteristic at this stage. After death, the body became hardened and brittle and was usually almost completely covered with the fruiting bodies of the fungus.

Many series of such tests, each containing from 50 to 100 mealybugs and showing consistent results, have established beyond doubt the parasitism of this fungus. The insects used were in various stages of development. There was no indication that the younger ones were more readily killed than the older, nor did the fungus appear to be more effective in killing one species than the other.

EFFECT OF TEMPERATURE.—After having established the parasitism of this fungus, it was desirable to determine the temperature at which the fungus would be most effective in killing mealybugs. This was of direct importance to the work of the insectaries, for this knowledge might suggest what temperature conditions should be maintained to prevent infection of the mealybugs reared as hosts for *Cryptolaemus*.

Six series of cultures were set up in a manner similar to that previously described, each petri dish containing 40 to 75 mealybugs. One series, together with a check culture, was placed in each of six controlled temperature chambers maintained at constant temperatures of 13°, 17°, 21°, 26°, 29°, and 31°, respectively. The cultures and checks were examined each day, and dead mealybugs noted.

In these tests the lowest temperature at which the fungus caused mealybug mortality was 21° C., a temperature requiring 72 hours to be effective. At successively higher temperatures the time required to cause death decreased somewhat, until at 29° C. only 36 hours were necessary. The optimum temperature for propagation of mealybugs in insectaries is around 27° C. It is possible, however, that during periods when infection by this fungus is likely to occur it would be of considerable economic importance to reduce the temperature to 20° C. or below.

OBSERVATIONS ON THE FUNGUS IN INSECTARIES.—Early in March, 1946, evidence of the parasitic *Aspergillus* fungus was found in insectaries in Orange and Los Angeles counties, California. In both locations a rainy period had immediately followed the periodic irrigation of the potatoes used as hosts for the mealybugs; the relative humidity indoors had consequently remained high and thus created favorable conditions for the growth of the fungus. Infection took place, and mealybugs died in considerable numbers in some of the rooms. This condition was, in general, readily altered when the relative humidity outside became lower, and when careful attention was paid to the amounts of water used in irrigating the potatoes. But in one of the insectaries, in a few rooms where the ventilation was very poor, the fungus was not checked so easily. The humidity remained high, and before they could be dried out a mortality reaching the proportions of 95 per cent of the mealybugs occurred in some parts of the rooms.

Fungicidal treatment does not seem practicable in dealing with a problem of this nature. Very careful irrigation practice and good ventilation appear to be most important in preventing losses of mealybugs from the attack of this fungus.

A yellowish-brown *Aspergillus* of the *A. flavus-oryzae* group was frequently present where the parasitic form was found. Very often both forms were found growing on the same dead mealybug.

This yellowish-brown form was most commonly found, however, as a saprophyte on dead parts of the potato plants. The evidence indicated that where both forms were growing on the same insect, the yellowish-brown form developed after the insect died. Several series of tests were carried out in an effort to determine whether or not this form could cause the death of mealybugs. In every test negative results were obtained. As stated above, this form was therefore found useful as a check in inoculation tests.

IDENTITY AND DESCRIPTION OF THE FUNGUS.—Upon general examination the parasitic fungus appeared to belong to the *Aspergillus flavus-oryzae* group. Specimens were forwarded to Dr. Charles Thom, Mycologist of the U. S. Bureau of Plant Industry, who suggested that although somewhat different it was probably closely related to *A. parasiticus* Speare, also a member of this group (Thom & Church 1921). *A. parasiticus* had been described by Speare (1912) as a new species attacking the sugar-cane mealybug, *Pseudococcus calceolariae*, in Hawaii. Transfers from the type culture had been kept by Dr. Thom ever since that time.

After three successive transfers of the type fungus from Hawaii had been made on glucose-potato-agar slants, cultures of this fungus and of the species isolated from mealybugs in California were set up and allowed to grow under identical conditions. Germination in both series occurred at about the same time, and growth was very similar for the first few days, after which that of the type fungus developed a much deeper shade of green. Conidiophores of the California fungus were about 200 to 300 microns in length, with diameter at base about 6 microns and at tip about 10.5 microns. The swollen vesicles were about 15 to 18 microns in length. Measurements of similar parts of the Hawaiian form were about the same as these. Spores of both forms were globular, but those of the Hawaiian form averaged larger.

The main differences between the two forms may be described as follows:

(1) The Hawaiian form is much greener in color than the California form, which presents a yellowish color almost devoid of green when growing on mealybugs and is only slightly greenish when growing on artificial media.

(2) The spores of the Hawaiian form (diameter, 3.4 to 6.8 microns; average, 5.5 microns) average considerably larger than those of the California form (diameter, 3.4 to 4.5 microns; average, about 4 microns). The following are measurements of 50 spores of each form.

SIZE CLASSES (DIAMETER IN MICRONS)	NUMBER OF SPORES	
	Hawaiian Form	California Form
3.4	4	23
4.5	20	27
5.6	4	0
6.8	22	0

(3) Spores of the California form are smooth; those of the Hawaiian form are conspicuously pitted and thus have a rough appearance. This is the most striking microscopic difference.

These differences in amount of green color and in spore size and appearance have persisted in cultures with repeated transfers over a period of 19 years, from 1928 to 1947. They indicate that the California mealybug fungus differs somewhat from the type culture of *Aspergillus parasiticus*, but not sufficiently, in our judgment, to make a new species or variety.

Other strains of *Aspergillus* similar to, but apparently not identical with, *A. parasiticus* Speare have been found on the sugarcane mealybug in British Guiana, Louisiana, Puerto Rico, Cuba, Santo Domingo, Barbados, and Trinidad, as reported by Johnston (1915), and in Egypt, as reported by Nattrass (1932). Strains of the *A. flavus-oryzae* group not so similar to *A. parasiticus* have also been found to be parasitic on mealybugs, as reported by Johnston (Thom & Church 1921).

Strains of the *Aspergillus flavus-oryzae* group have also been shown to parasitize other insects such as *Drosophila*, which was killed in 24 hours at 28° to 30° C., according to Blochwitz (1929). Another strain was almost always fatal to certain birds, when inoculated by inhalation (Verge 1928).

SUMMARY.—In the propagation of mealybugs in California insectaries, a fungus closely related to *Aspergillus parasiticus* Speare has been found to be a

potentially serious parasite under conditions of high humidity and moderate-to-high temperatures.

In artificial cultures the fungus killed the mealybugs at temperatures ranging from 21° to 31° C., with exposure periods varying from 72 hours at 21° to less than 36 hours at 31° C. Temperatures of 13° to 17° C. were too low to cause death of the insects, even when inoculated with abundant spores.

At times when infection by the fungus is likely to occur in insectaries where mealybugs are being propagated, the following measures are suggested: good ventilation, very careful irrigation of the host plants, and a lowering of the temperature to 20° C., or below.

LITERATURE CITED

Blochwitz, A. 1929. Schimmelpilze als Tierparasiten. (Vorläufige Mitteilung.) Deut. Bot. Gesell. Ber. 47: 1, 31–4.

Boyce, A. M., and H. S. Fawcett. 1928. An *Aspergillus* attacking mealybugs in insectaries in southern California. (Abstract) Phytopath. 18: 948.

Fawcett, H. S. 1944. Fungus and bacterial diseases of insects as factors in biological control. Bot. Rev. 10: 327–48.

Johnston, John R. 1915. The entomogenous fungi of Porto Rico. Porto Rico Bd. Commrs. Agr. Bul. 10: 1–33.

Nattrass, R. M. 1932. Preliminary notes on some entomogenous fungi in Egypt. Egypt Min. Agr. Tech. and Sci. Serv. Bul. 120. 9 p. 6 pl. (Rev. Appl. Mycol. 13: 94. 1934).

Smith, Harry S., and H. M. Armitage. 1931. The biological control of mealybugs attacking citrus. Calif. Agr. Exp. Sta. Bul. 509: 1–74.

Speare, A. T. 1912. Fungi parasitic upon insects injurious to sugar cane. Hawaii. Sugar Planters' Assoc. Exp. Sta., Div. Path. and Physiol. Bul. 12: 1–62.

Thom, Charles, and Margaret B. Church. 1921. *Aspergillus flavus, A. oryzae*, and associated species. Amer. Jour. Bot. 8: 103–26.

Thom, Charles, and Kenneth B. Raper. 1945. Manual of the Aspergilli. 373 p. Williams and Wilkins Company, Baltimore.

Verge, J. 1928. Les aspergilloses des oiseaux. Rec. de Méd. Vét. 103: 521–28.

Investigations on the White-Fringed Beetle Group in South America

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Investigations on *Graphognathus* spp. were started in South America in September 1938, and have been continued as time and opportunity have permitted. Emphasis has been placed on searching for natural insect enemies that would be of aid in controlling *G. peregrinus* Buch. and the races of *G. leucoloma* (Boh.) in the United States. These species were discovered in North America in 1936 and later, and have attacked various cultivated crops in several southern States. Information on the discovery, abundance, and biology of the white-fringed beetle in North America has been published by Young & App (1939).

[1] The writer acknowledges with thanks the aid received from the following workers: H. L. Parker for directing the project and supplying material; L. L. Buchanan for identifications; Juan M. Bosq for accompanying him on his first field trips in Argentina and for specimens of various species that occur in Argentina; D. S. Bullock for providing working quarters in Angol, Chile, and for much information on the habits of *Pantomorus* and *Graphognathus* in southern Chile.

In a previous publication the writer (Berry 1939) gave an account of his observations on the group in Argentina, Uruguay, and Brazil. Since that time additional studies have been made, and the survey has been extended to include Chile.

Previous to these investigations little was known of the biology and habits of the various species and strains of *Graphognathus* that are so common in some of the South American countries, though the adults of white-fringed beetles were well known in Argentina, where several species have been recorded from the various provinces. Available information indicated that all the species and races of *Graphognathus* were of South American origin, and that they were not serious pests in their native habitat. It seemed probable that natural insect enemies were the controlling agents in the areas

where they developed. Other natural enemies, such as birds, disease-producing organisms, and nematodes, were considered as possible controlling agents. Data on cultural methods in relation to population densities were obtained where possible, but in most cases accurate information was not obtainable. Emphasis was placed on determining the distribution of *Graphognathus* in South America, but much more time and more investigators would have been necessary to fix, even approximately, the southern and northern limits of distribution of the described kinds of white-fringed beetles, or of other races closely related to those occurring in the United States. Data on all phases of biological and ecological factors affecting the development and abundance of the white-fringed beetles were obtained in so far as possible during the investigation.

Samples of all species of Curculionidae pertaining to the *Graphognathus* group, obtained during the course of the work, were sent to the United States National Museum for determination.[2]

DISTRIBUTION.—The *Graphognathus* group of beetles is distributed over an extensive area in South America. Buchanan (1939) lists *G. leucoloma* as occurring in Lima, Peru, which is the northern limit of its known range on the west coast of South America. Cortes (1941) states that *G. leucoloma* has been recorded from Castro and Ancud, Chile, which is the southernmost point at which it has been found. The first of these three records refers certainly, the second and third probably, to races of the *G. leucoloma* complex, but not to the true *G. leucoloma*. The last two records are somewhat doubtful and will be verified, if possible.

The writer obtained adult specimens of *Graphognathus* in all agricultural sections of Chile from Copiapo in the north to Temuco in the south. Data obtained during the survey show rather conclusively that the species and races of white-fringed beetles are few and individuals scarce outside the above-mentioned limits. Extensive searches were made from Temuco south to Magallanes in Chile and throughout the coastal areas of Peru, but not a single specimen was found.

East of the Andes mountains the known range of the *leucoloma* group extends from Santa Maria, Brazil, in the north, to Rio Colorado, Argentina, in the south. It has been recorded by Juan M. Bosq (1934) from the following localities: Argentina; Provinces of Buenos Aires, Santiago del Estero, Cordoba, San Luis, and Salta.

Graphognathus is generally distributed throughout the cultivated areas of Uruguay and Argentina. The present known limits are restricted to the zone between 27° and 29° south latitude. Outside these zones races or species undoubtedly exist, but it seems certain that the infestations are not of economic importance.

ABUNDANCE AND DAMAGE.—Adult populations of white-fringed beetles have been rather light in all areas studied in South America, and none compare in density with those observed in the United States and recorded by Young and App (1939). Four fairly dense populations have been studied during the last 6 years. Two of these occurred at La Serana and Vicuna, Chile, from March to May in 1940 and during the first part of April 1941, the last time that observations were made in Chile. Densities of populations were judged by the numbers of adults that could be collected by 1 man in 1 hour. In Vicuna and La Serana the average for 30 hours' collecting was 39 adults per man-hour. Another fairly dense population was observed in Angol, Chile, during January and February 1941. Here the rate of collecting was 33 adults per man-hour. In this case there was no migration of a general nature, but a general dispersion in all directions from the focal points where the infestation was most intense.

The fourth relatively dense population of adults was observed in Montevideo, Uruguay, during March and April 1943. Here a number of forms were involved. The adults in this case as in others were migrating and were collected at an average rate of 40 adults per hour.

In all other observations adult populations were not dense and were generally restricted to isolated individuals. Gen-

[2] In a recently published paper (Buchanan 1947) the following changes in the classification of the white-fringed beetles have been proposed:

1. *Graphognathus*, which includes all white-fringed beetles, and which was formerly considered a subgenus of *Pantomorus*, is raised to generic rank.
2. Of the seven distinguishable kinds of white-fringed beetles present in the United States, five are reduced from the rank of species to that of race, and are placed as members of the *leucoloma* complex; the remaining two (*peregrinus* and *minor*) are retained in their original status as species.
3. The true *leucoloma* of Boheman (i.e., *leucoloma leucoloma*), as was determined by an examination of the type specimen, does not occur in the United States, and what has hitherto been called *leucoloma* in North American reports is described as a new race of the *leucoloma* complex.

erally speaking, collections of 8 to 20 adults per day were considered good. Dense populations of adults were reported in Argentina, as well as in Chile, but these apparently occurred infrequently, and no definite data have been obtained on the density of these populations.

LARVAL POPULATIONS.—During the most intensive work, from September 1938 to March 1943, larval populations were studied in Chile, Argentina, and Uruguay. The work was spread out over so much territory and continued for such short periods in each area that sufficient samples could not be obtained to give adequate information on the densities of populations. However, a general idea of the abundance and damage can be obtained from the following figures: In Chile 204 alfalfa fields were examined, and samples showed populations ranging from 0 to 140 larvae per square yard. Averages for distinct zones were as follows: Copiapo 6.0, Vallenar 3.0 in April 1940; Vicuna 6.6 in April and May, and 13.5 in August 1940; La Serana 4.0 in April and May, and 16.0 in August; San Bernardo 35.3 in February 1941; Linares 14.0 in February and 11.4 in June 1940; Angol 31.8 in February, and 20.0 in July 1940; 14.5 in January, and 37.0 in March 1941. These averages show considerable variation, but the increases in most cases were due to the increase in small larvae. Samples were taken under conditions as uniform as possible, but they were probably not large enough to be truly representative of the areas investigated. In Argentina and Uruguay sampling was done on a reduced scale except in Tucuman, Argentina, where several square yards of soil were examined for each sample. In Argentina the larval population per square yard ranged as follows: at Jujuy from 12 to 30 in the most densely infested zones, at Salta 1 to 10, at Tucuman 5 to 212, at Pergamino 3 to 18, and at San Juan 0 to 30. In Uruguay the heaviest infestations were found near Paysandu, where 30 to 96 larvae per square yard were found. It should be kept in mind that these figures represent the densest populations of *Graphognathus* larvae that could be found, not the average for the areas studied. The Chilean records represent fairly accurately the average *Graphognathus* larval populations in alfalfa fields planted for 2 to 3 years or more, but do not include other types of crops or young alfalfa plantings of less than 2 years.

Samples were taken in many types of planting, such as corn, wheat, pasture land, and truck gardens, but usually populations in such areas were so low that sufficient larvae could not be obtained for examination for parasites.

The figures on larval populations are significant, in that they show the general distribution of *Graphognathus* in the agricultural areas of South America. The infestations are at times dense enough to cause considerable damage. Damage to corn or cotton has not been observed in South America, although many fields in which corn has followed alfalfa or clover have been examined.

The principal crops in which damage by white-fringed beetles has been observed by the farmers are beans, strawberries, lettuce, pepper, and nursery plants. Infestations in all these types of crops have been observed, and considerable damage to beans and lentils was occasioned in Chile. Bullock (1940) first noted the damage by an insect of this group in Angol. He stated that "in the region of Angol this insect is so destructive in some years, in bean plantings, that it is necessary to seed the fields for the second time. This was the case in 1936. In other years they were very scarce and damage is practically unnoticed."

The writer has observed serious damage to beans, nursery stock, and lettuce in southern Chile, near Angol. Damage to potatoes was seen in many parts of Chile, and several larvae were taken from a potato storage bin in Quillote, Chile. Damage to alfalfa has been noted in Tucuman, San Juan, and other localities in Argentina. Severe damage to strawberry plantings has been observed in Uruguay, even though infestations were quite light in the cases studied. It appears that the larvae migrate from one plant to the other, a few therefore doing damage out of all proportion to their numbers.

In general it can be said that considerable damage is done by the *Graphognathus* group of beetles in South America. The most destructive species cannot be discussed until a more thorough and systematic study of the group has been completed. Many more collections and field studies should also be made before a comprehensive analysis could be made regard-

ing the relative importance of the species and races involved. It may be stated that several of them are serious crop pests, and all precautions should be taken to prevent their entry into the United States.

Larval populations were higher in sandy loam soils than in the heavy clay types as a general rule, but occasionally populations were dense in the compact soils. Soils heavily pastured generally had lower populations of larvae, but whether that was due to the packing of the soil or to other factors, such as lack of food plants to attract the adults for oviposition, was not determined.

SEASONAL HISTORY.—Sufficient work has not been done to give an accurate account of the seasonal history of any one species or race of *Graphognathus*. Adults of this group of beetles are usually most abundant from January to April in most areas where they have been found. In some sections, as in Angol, Chile, solitary adults may be found in almost any month of the year, but they were abundant only during January and February. In northern Chile rather dense populations were observed in La Serana and Vicuna from March to May in 1940, and beetles were abundant in the same area in April 1941, the only period during which observations were made that year. In Montevideo adults were abundant during April and May 1943. The species studied in Chile consisted of one race in Angol and possibly another closely related race in La Serana and Vicuna. The species in Montevideo consisted of several races. There is no specific time at which emergence of adults of white-fringed beetles takes place throughout the infested territory, but this is more or less confined to the summer and fall, or from December to June. Important factors that may affect the time of emergence are temperature, irrigation, and rainfall.

Egg deposition presumably goes on in the field at any time that females are present. No eggs were found in the field, although much time was spent searching for them while infestations were the heaviest. Several adults were confined singly in cages, but they deposited few eggs. Many egg masses were obtained from large cages where several hundred adults were confined. Dissection of adults soon after their death revealed that their abdomens were distended with eggs, many of which seemed to be mature. Why they died before laying their eggs has never been explained, as they were fed on alfalfa and beans, the same foods that they had in the field. The eggs that were kept under observation hatched in 14 to 16 days during January and February in Angol, Chile.

Larval development was not followed through a generation, but apparently larvae remain in the soil for 2 years in Angol. Observations were started there in January 1940, at which time many large and no small white-fringed beetle larvae were found. The populations remained about the same until emergence started in December 1940, and populations of large larvae were considerably reduced in February 1941, when emergence of adults was practically complete. In La Serana and Vicuna, or nothern Chile, a generation per year, with a small carry-over, appeared to be normal. After adult emergence in 1940 there were few large larvae left in the ground, and adults, as has been mentioned, were again abundant the following year. Information on time required for larval development in other South American countries is fragmentary, but the development probably follows the same pattern as in Chile, that is, a generation a year in the North and a generation every 2 years in the South.

NATURAL ENEMIES.—Work was initiated to obtain natural enemies that would aid in the control of the white-fringed beetles now established in the United States. Up to the present, however, no such enemies have been found, and it appears unlikely that any effective insect enemies exist. Extensive studies have been made, and thousands of larvae have been examined for indications of parasites or diseases. Few dead larvae were found in the soil, and none of them contained disease organisms that affected living larvae. Several thousand adults have also been examined and kept in rearing cages, but no parasites have been found to attack them. Observations in the field for predatory Hymenoptera have been made in all heavy infestations, but no instance of adults attacked by solitary wasps has been observed. The egg stage also was free from attack by parasites and predators.

Birds may be of some importance in the control of the *Graphognathus* group in South America, but it is doubtful that

they play any great part in reducing the populations. The most important bird in insect control appears to be the Tiuque, *Milvago chimango chimango* (Vieillot). This species is very abundant in Chile, and hundreds have been seen in the fields following plows or other types of cultivation that bring the soil larva to the surface. Another species is known as Quelteque, *Belonopterus chilensis chilensis* (Molina), which is also abundant in Chile. Both these birds are attracted to fields where insects are prevalent, and at the sound of a tractor they immediately come to investigate the possibility of finding insect larvae in its wake.

AGRICULTURAL PRACTICES.—No general agricultural practices have been developed to combat the white-fringed beetles in South America. The soil, however, is well cultivated in most sections before planting. Early plowing, then cross plowing again shortly before seeding, is the general practice for most cultivated crops. This practice, although apparently developed to rid the soil of weeds and to pulverize the clods, greatly decreases the population of soil-infesting larvae. In irrigated areas where beans are grown, a method to combat white-fringed beetles has been devised. This consists in cultivating the bean fields in such a way as to throw the soil up around the base of the bean plants, and then irrigating immediately. Damage to the bean crop is often reduced by this method; it does not kill the larvae that do damage, but gives the beans a more vigorous growth, which tends to offset the injury. The same effect has been noted in heavily attacked alfalfa fields. When plants begin to die, irrigation is resorted to in order that the plants may be revived. Often many apparently dead alfalfa plants, damaged by white-fringed beetle larvae, can be found in fields that have been dry for several weeks, but following irrigation there is a decided recuperation, and infestations cannot be detected from the wilted or dead plants.

SUMMARY.—The white-fringed beetles, *Graphognathus*, are distributed over a large area of South America, the known range being from Ancud and Castro, Chile, and Rio Negro, Argentina, in the south, to Lima, Peru, and to Santa Maria, Rio Grande do Sul, Brazil, in the north.

Populations of these beetles are relatively low throughout the agricultural areas of South America, but many infestations dense enough to cause serious damage to various cultivated crops have been found. The principal crops damaged were beans, alfalfa, and strawberries; other damage was mostly confined to garden crops, such as lettuce and peppers, and other small plants.

Larval populations in general are more dense in sandy loam soils than in the heavy clay types in practically all cases. They are scarce in practically all types of cultivated crops, dense infestations having been found only on alfalfa and clover of 2 or 3 or more years' standing.

The seasonal history appears to vary according to climatic conditions, the life cycle in the southern part of the range requiring 2 years, while a generation a year appears to be the rule in the north.

Natural insect enemies of the white-fringed beetles have not been found in South America. Two species of birds, *Milvago chimango chimago* and *Belonopterus chilensis chilensis*, feed on the larvae, but probably have little effect in reducing the populations, as they have access to the larvae only during cultivation.

LITERATURE CITED

Berry, P. A. 1939. Report on a survey in South America of the white-fringed beetle and its natural enemies. U. S. Bur. Ent. and Plant Quar. **E-487.**

Bosq, Juan M. 1934. Primera lista de los Coleopteros de la Republica Argentina, daninos a la agricultura. Argentina Min. de Agr. de la Nacion Bol. **36:** (313)–344.

Buchanan, L. L. 1939. The species of *Pantomorus* of America north of Mexico. U. S. Dept. Agr. Misc. Pub. **341.**

Buchanan, L. L. 1947. A correction and two new races in *Graphognathus* (white-fringed beetles). Wash. Acad. Sci. Jour. **37:** 19–22.

Bullock, D. S. 1940. El "Gusano de los Porotos" (*Naupactus leucoloma* Boh.), una plaga en los Estados Unicos. Rev. Chilena de Hist. Nat. Pura y Aplicada **44:** 38–41.

Cortés, Raul P. 1941. Acerca del gen. *Pantomorus* Schoenh. (Col., Curculionidae) in Chile. [Chile] Min. de Agr., Bol. de. Depart. de Sanid. Veg. **1:** 61–3.

Young, H. C., and B. A. App. 1939. Biology of the white-fringed beetle (*Naupactus leucoloma* Boh.) U. S. Bur. Ent. and Plant Quar. **E-464.**

Methods of Calculating and Correcting the Mortality of Insects[1]

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In a study of the effectiveness of insecticides on insects, the percentage mortality may vary to a great extent depending on the methods used to determine and to express mortality. Laboratory research involving the fumigation of the granary weevil, *Sitophilus granarius* (L.), and the confused flour beetle, *Tribolium confusum* Duv., with carbon disulfide revealed that various criteria of death as well as the length of time between fumigation and counting the number of dead insects can produce a wide fluctuation in mortality with a maximum variation of 47 per cent depending upon how and when the insects were counted.[4] When dealing with aphids or other insects which reproduce rapidly, the rate of reproduction is another important factor which affects final results given in terms of mortality. It is a general practice to set aside checks which are carried along with the treated insects so as to correct for the natural mortality by Abbott's formula (1925). However, if there is an increase in population in the check it is usual to take the natural mortality as zero, without considering the effect of the increase in population on the mortality in treated lots. If only adult insects are used in an experiment the mortality of adults can easily be counted. However, if the whole population of insects is used in testing the effectiveness of insecticides, either in the laboratory or in the field, the usual way of counting mortality may give misleading results for certain species of insects with a rapid rate of reproduction.

The senior author[4] found that the population of potato aphid, *Macrosiphum solanifolii* (Ashm.), melon aphid, *Aphis gossypii* Glov., bean aphid, *A. fabae* Scop. (Muesebeck, 1946; formerly called *A. rumicis* L.), and cabbage aphid, Brevicoryne brassicae (L.), increased 37.6, 60.5, 24.1 and 108.9 per cent respectively in greenhouse tests and the population of bean aphid increased 57.7 per cent within 24 hours in a field test. In unpublished results with onion thrips, *Thrips tabaci* Lind., the population in the check increased 37.2 per cent and 819.0 per cent respectively at the end of one and three days. Evidently increases in population during an experimental period are not confined to aphids, but may occur within other groups of insects where young larvae or nymphs hatch from eggs, and become part of the same general population to which the adults belong.

EXPERIMENTS AND METHODS OF CALCULATION.—Several pea aphids, *Macrosiphum pisi* (Kltb.), were transferred to each of twelve pots of broad bean plants. After three days of reproduction each plant contained aphids of various ages. The top of each pot was covered with a sheet of white paper with a hole at the center, so cut and arranged that a paper floor was formed and those aphids affected by insecticides would fall on the paper. Dusting was done on a turn-table as described in a previous paper (Sun 1946). The dust deposited on the paper was carefully brushed off and the whole plant placed under a lantern globe, the top of which was covered with two layers of cheese cloth. All pots were then transferred into a constant temperature room maintained at 24° to 25° C. and provided with light. The number of adults and nymphs was counted before dusting and also one day after dusting. Aphids feeding on plants and those crawling on paper were considered as alive.

The results of dusting experiments with rotenone-containing dusts against pea aphids are presented in table 1. Adults and nymphs found on the plants before dusting were counted separately as were the young aphids born after dusting. Depending on the basis of calculation, mortality may be determined in six (perhaps more) different ways: (1) mortality of adults, (2) mortality of nymphs present before dusting, (3) mortality of young aphids born after dusting, (4) mortality of all ages of aphids present on the basis of mortality counts made after dusting, (5)

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[3] Acknowledgement is made to Drs. L. B. Norton and W. A. Rawlins for their critical reading of this paper.

[4] Sun, Y. P.—Unpublished reports.

mortality based only on the adults and nymphs which were present on the plant previous to dusting, and (6) apparent mortality of aphids, i.e., on the basis of the difference between the numbers of live aphids before and after dusting, no counts of dead aphids being made. The last one is a convenient method for the computation of mortality of insects on living plants and undoubtedly many expressions of mortality have been made on this basis. These methods of calculating mortality may be expressed by the following equations.

Let A_t = Total number of living adults before dusting.
A_d = Adults dead after dusting.
N_t = Total number of nymphs present before dusting.
N_d = Nymphs present before dusting but dead at the time of counting mortality.
Y_t = Total number of young aphids born after dusting.
Y_d = Young aphids born after dusting but dead at the time of counting mortality.

$$\text{Percentage mortality of adults} = \frac{A_d}{A_t} \times 100 \tag{1}$$

$$\text{Percentage mortality of those nymphs present before dusting} = \frac{N_d}{N_t} \times 100 \tag{2}$$

$$\text{Percentage mortality of young aphids which were born after dusting} = \frac{Y_d}{Y_t} \times 100 \tag{3}$$

$$\text{Percentage mortality of all aphids} = \frac{A_d + N_d + Y_d}{A_t + N_t + Y_t} \times 100 \tag{4}$$

$$\text{Percentage mortality of dusted aphids} = \frac{A_d + N_d}{A_t + N_t} \times 100 \tag{5}$$

$$\text{Apparent percentage mortality on basis of living aphids only} = \frac{(A_t + N_t) - [(A_t - A_d) + (N_t - N_d) + (Y_t - Y_d)]}{A_t + N_t} \times 100$$

$$= \frac{A_d + N_d + Y_d - Y_t}{A_t + N_t} \times 100 \tag{6}$$

Mortality results from dusting pea aphids were calculated according to each of the above equations (Table 1). Naturally the results differ widely because of the segregation of populations of differing susceptibilities. Although too few adults were used for a careful comparison of age groups the adults (Equation 1) give far different results from dusted nymphs (Equation 2). The apparent mortality (Equation 6) will equal the actual mortality of dusted aphids (Equation 5) if all the young aphids born after dusting are killed, i.e. if $Y_d - Y_t = 0$ in Equation 6. In fact, the difference between apparent mortality and the mortality of aphids actually dusted depends not only upon the per cent of young surviving at the time of counting mortality but on the young born after dusting. At high concentrations of insecticides which produce high mortality, the percentage of young aphids surviving at the time of counting mortality is likely to be low and therefore any effect upon apparent mortality is not as great as in those treatments producing low mortality. If there were no reproduction after the application of insecticides, Equations 4, 5, and 6 would be the same.

A number of these calculations of mortality require that all aphids involved in a treatment be found. In practical experiments for controlling insects it is usually impossible to count all the insects, both alive and dead, and Equation 6 is not accurate enough as an indication of the mortality of insects, although it is a practical way to obtain the percentage mortality without comparing the treated population with a check.

Because of the difficulty of finding all the insects involved in a field treatment, the effectiveness of an insecticide is often expressed as in terms of the reduction in a population of insects as compared with a check, using a standard method of sampling insects. By this method of expressing the results of control, a large error is liable to exist when the distribution of insects is not uniform (Table 3). To avoid such misleading results, the following method of calculation, derived from a theoretical population, is suggested as an approach to

Table 1.—Mortality of pea aphids calculated by different methods; number in parentheses indicates equation applied.

Pot No.	No. of Adult Aphids Before Dusting		No. of Nymphs Before Dusting		No. of Aphids Born After Dusting		Per Cent Mortality, After 24 Hours					
	Total	Dead	Total	Dead	Total	Dead	Adults (1)	Nymphs (2)	Newborn (3)	All Aphids (4)	Dusted Aphids (5)	Apparent (6)
I. 0.25 Per Cent Rotenone Dust												
1	4	1	98	71	46	17	25.0	72.3	36.9	60.1	70.6	57.8
2	7	1	127	99	87	36	14.3	78.0	41.3	61.7	74.6	63.4
3	5	1	85	64	53	23	20.0	75.2	43.4	61.5	72.2	61.1
4	5	0	144	114	72	29	0	79.2	40.2	64.9	76.5	52.3
5	4	1	86	73	53	16	25.0	84.9	30.2	62.9	82.1	58.9
6	4	1	84	64	23	7	25.0	76.2	30.4	64.8	73.9	44.2
						Average	18.2	77.6	37.1	62.7	75.0	56.3
II. 0.5 Per Cent Rotenone Dust												
1	3	1	49	46	15	15	33.3	93.8	100.0	92.6	90.3	90.3
2	7	4	67	66	72	65	57.2	98.5	90.3	92.5	94.6	85.2
3	5	2	124	112	54	33	40.0	90.3	61.1	80.3	88.3	72.0
4	5	5	97	84	25	21	100.0	86.6	84.0	86.6	87.2	83.3
5	6	4	186	163	68	49	66.6	87.6	72.0	89.2	96.0	85.1
6	5	3	72	69	51	43	60.0	96.0	84.3	89.8	93.5	83.1
						Average	59.5	92.1	82.0	38.5	91.7	83.2

determining the effectiveness of insecticides in a practical way.

Since the population of insects in a check may increase during the period between dusting and counting mortality, a corresponding increase on the treated plants would occur, if no insecticides were applied. Because of the action of insecticides on insects of treated plots, their reproduction in most cases would not be as high as that in the check. Therefore, the actual population in the treated plots is less than the theoretical population. There is no way to figure out how many young aphids are produced in treated plots. However, if the action of insecticides is expressed in terms of their effectiveness in population reduction instead of in terms of percentage mortality, the decrease in reproduction of insects in treated plots, being due to the action of insecticides, should be counted as part of the effectiveness of the treatment. The following equation is derived on the basis of the above reasoning.

Let C_b = Population of insects in the check just before dusting.
C_c = Population of insects in the check during counting of mortality.
T_b = Population of insects on treated plants just before dusting.
T_c = Population of insects on treated plants during counting of mortality.
P_t = Percentage mortality of treated insects obtained by Equation 6.
P_c = Percentage increase in population in check during the period between dusting and counting mortality.

The theoretical population of insects on treated plants at the time of counting mortality would be

$$T_b \cdot \frac{C_c}{C_b} \text{ or } T_b\left(1+\frac{P_c}{100}\right) \text{ and, therefore:}$$

Corrected percentage reduction in population (for increases of population in the check)

$$= \frac{\left(T_b \cdot \frac{C_c}{C_b}\right) - T_c}{T_b \cdot \frac{C_c}{C_b}} \times 100$$

$$= \frac{T_b\left(1+\frac{P_c}{100}\right) - T_c}{T_b\left(1+\frac{P_c}{100}\right)} \times 100$$

$$= 1 - \frac{T_c}{T_b\left(1+\frac{P_c}{100}\right)} \times 100$$

$$= \left[1 - \left(1 - \frac{P_t}{100} \right) \cdot \frac{1}{1 + \frac{P_c}{100}} \right] \times 100$$

$$= \left[\frac{1 - \frac{P_t}{100}}{1 - \frac{P_c}{1 + \frac{P_c}{100}}} \right] \times 100$$

$$= \frac{1 + \frac{P_c}{100} - 1 + \frac{P_t}{100}}{1 + \frac{P_c}{100}} \times 100$$

$$= \frac{P_t + P_c}{100 + P_c} \times 100 \qquad (7)$$

If the population of insects in the check decreases the same method used in the derivation of Equation 7 can be applied with the same reasoning. P_k, the percentage decrease in population in the check, is used instead of P_c. The theoretical population in the treated plots will be $T_b(1 - P_k/100)$ instead of $T_b(1+P_c/100)$ and the equation will be as follows:

Corrected percentage reduction in population (for decreases of population in the check)

$$= \frac{P_t - P_k}{100 - P_k} \times 100 \qquad (8)$$

By combining Equations 7 and 8, a general equation is obtained for the correction of population in treated plots whether the population in the check increases or decreases during the experimental period.

Corrected percentage reduction in population (for either increases or decreases of population in the check)

$$= \frac{P_t \pm P_{ck}}{100 \pm P_{ck}} \times 100, \qquad (9)$$

where P_{ck} is the percentage change of population in the check. The sign in Equation 9 will be positive if the population increases, and negative, if it decreases.

DISCUSSION.—The application of Equations 6 and 9 is illustrated in the recalculation of the results on cabbage aphids from a previous paper.[1] It is shown in table 2 that the actual percentage reduction in population is higher than the original calculation. The differences are greater at low than at high percentages and apparently such differences would be negligible as the results approach 100 per cent. These differences in effectiveness are due to the number of young born after dusting and the proportion of them which survive until mortality is determined.

Based on check populations, the values for percentage reduction in cabbage aphids in Table 2 are about the same as values calculated by Equation 9. This happens only when the population of insects is rather uniformly distributed. If the population in the check were only half of the original one and the percentage increase in population remained the same, i.e. an average of 83.9 and 102.1 aphids on each potted plant at the end of one and three days respectively, the percentage reduction of population on the basis of the check would be 8.5 and 22.3 per cent instead of 54.2 and 68.1 per cent for 2 per cent DDT dust. On the other hand, if the

Table 2.—Toxicity of dusts containing DDT and *Velsicol AR-60* to cabbage aphids of various ages (from Sun, 1946, recalculated; greenhouse test on cabbage).

Toxicant Content of Dust		Total Aphids Before Dusting (6 pots)	Average Per Cent Mortality (Equation 6)		Corrected Percentage Reduction in Population (Equation 9)		Percentage Reduction in Population on Basis of Check	
DDT, Per Cent	*Velsicol AR-60*, Per Cent		1 Day	3 Days	1 Day	3 Days	1 Day	3 Days
2	—	710	36.0	45.6	55.4	69.9	54.2	68.1
5	—	686	55.4	74.5	68.9	85.9	69.5	85.8
2	3	810	85.9	99.2	90.2	99.5	88.9	99.4
Check (no dust)		724	43.4[1]	80.6[1]				

[1] Percentage increase in population.

[1] Sun, 1946. Unpublished report.

population in the check were twice the original one, the reduction of population would be 77.1 and 84.0 per cent for the same dust. The results in terms of population reduction, calculated in the two ways would be the same, only when the population of insects before the application of insecticides is exactly the same on both untreated and treated plants.

Often in field experiments when the effectiveness of insecticides is expressed in terms of population reduction on the basis of the number of insects in an untreated check, the original population of insects before treatment is not given. This makes it impossible to compare other methods of calculation. However, Ditman's data (1946) which include figures for the population of pea aphids both before and after treatment provide a good example. Because of wide variations in the original population of aphids it appears unfair to show the reduction in population by comparing the number of aphids in the treated plots with those in the untreated check where there were several times as many aphids per sweep than in some of the treated plots. The results recalculated by Equation 9 are from 14.4 to 40.2 per cent lower than the original figures, and the order of effectiveness of these treatments is: $C>D>B>E$ (recalculated) instead of $D>C>E>B$ (original) (Table 3). This situation is due to the excessively large population in the check and unequal populations in treated plots. If the plot with the smallest population of aphids had been made the check, the figures for percentage reduction in population would have been much lower.

Table 3.—Results of DDT spray treatments for control of pea aphid on experimental plots at Laytonsville, Maryland. Treatments applied May 23 (Ditman 1946; recalculated).

Treatments	Average Number of Aphids per Sweep		Per Cent Reduction on Basis of Check on May 28 (Ditman)	Per Cent Reduction Recalculated by Equation (9)	Difference in Calculated Percentage of Control
	May 23, before Treatment	May 28, after Treatment			
A—Untreated Check	887.4	1058.0	—	—	—
B	417.0	219.7	79.2	55.8	23.4
C	307.2	80.5	92.4	78.0	14.4
D	267.7	72.5	93.1	77.3	15.8
E	283.7	199.4	81.2	41.0	40.2

Abbott's formula becomes the same as Equation 9 if the percentage of living insects is converted into percentage of dead ones or vice versa, although these formulae were obtained independently by different means. By using practical examples it was found that the same results can be obtained for both increases and decreases in check population when either equation is used. In presenting the formula for correcting results for natural mortality Abbott (1925) reasoned as follows: (1) The difference between the percentage of living scales in the untreated check and the percentage of living scales in the treated plot gives the percentage of the original number actually killed by the treatment. (2) When a certain number of scales, as for example 20 per cent, is found to have died from natural causes, it logically follows that only 80 per cent of the original infestation was living and could have been killed by the treatment applied. (3) Since only 80 per cent of the insects could have been killed by the spray the "per cent control" would be determined by comparing the number actually killed with the number of *living* scales in the check.

In the literature Abbott's formula has been used almost exclusively for the correction of natural mortality. However, Gyrisko *et al.* (1945) stated "The populations in the control plots were adjusted by means of Abbott's formula to correct for increases or decreases of the check." They did not give the data for check plots, the difference in control before and after the correction, or the reasons for adopting Abbott's formula for the correction for increases in population. Gyrisko[1] used Abbott's formula in the correction of increases in population, but failed to mention clearly its application when the results were published (Gyrisko 1946). The derivation of Equation 9 supports the

[1] Gyrisko 1945; unpublished report.

application of Abbott's formula not only for correcting for natural mortality but also where increases in population are involved. Actually, natural mortality and reproduction occur at the same time and the observed increases and decreases in population are the net values of the two phenomena.

SUMMARY.—The use of Abbott's formula in the correction of natural mortality is a common practice, but no serious consideration has been given to the correction of results when an increase in population is observed. It was reported in a previous paper (Sun 1946) that an increase in population of aphids affecting the results of calculation is even more serious than natural mortality. Further observations indicate the same is true of thrips and other insects where numerous young individuals are continually added to the population.

To determine the differences in results obtained by making mortality counts in several ways, experiments with pea aphids on potted plants were carried out (Table 1). As a result of these observations a general equation was derived from theoretical populations on treated plants so that results can be corrected for increases or decreases in population. The corrected percentage reduction in population in treated plots $= \frac{P_t \pm P_{ck}}{100 \pm P_{ck}} \times 100$, where P_t is the percentage of apparent mortality (Equation 6) in treated plots and P_{ck} is the percentage change of population in the check. The sign in the above equation will be positive when the population in the check is increased, and negative, when it is decreased. This equation is similar to Abbott's formula which was derived on the basis of the percentage of living insects, and strongly supports the use of the latter where there are increases in populations in untreated plots.

It was found that in the case of an increase in the check population the apparent mortality is generally smaller than when the results are calculated by the above equation. Only when the population of insects is uniformly distributed is the percentage reduction of population calculated on the basis of the population of the check about the same as that obtained by the suggested equation. A population not uniformly distributed will give misleading results, even if the percentage of change in population remains the same. The suggested equation eliminates large errors from this source.

LITERATURE CITED

Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. JOUR. ECON. ENT. 18: 265–7.

Ditman, L. P. 1946. DDT preparations for control of the pea aphid. JOUR. ECON. ENT. 39: 219–22.

Gyrisko, G. G., J. F. T. Jodka, and W. A. Rawlins. 1945. DDT to control potato insects. JOUR. ECON. ENT. 38: 169–73.

Gyrisko, G. G. 1946. Some new insecticides for potato insect control. JOUR. ECON. ENT. 39: 262–3.

Muesebeck, C. F. W. 1946. Common names of insects approved by the American Association of Economic Entomologists, JOUR. ECON. ENT. 39: 427–48.

Erratum. In the August issue, Vol. 40, page 597, table 2, at the top of column 2, certain minus signs were omitted. The following reproduction of the table shows the position of these signs. (Paper by Ephriam Hixson and Martin H. Muma.)

Insecticides causing total mortality to chicken mites on various wood surfaces.

	TIME IN DAYS FOR TOTAL MORTALITY				
	Rough wood	Smooth wood	Press board	Painted smooth wood	Painted press wood
Azobenzene	14	10−[1]	18	9−	9
Hexachlorocyclohexane	14	10−	14−	9−	9−
Pentachlorophenol	21	21	18	18	18
Carbolineum	21	21	18	18	18
DDT kerosene	21	21	18	18	18
DDT water suspension	21	21	18	18	18

[1] A minus sign indicates that the exact number of days is not known but was less than the number given.

DDT and Other Insecticides for Squash Borer Control[1]

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Experiments by various workers (Tate, *et al.* 1945; Parker 1945; Bruce & Tauber, 1945) have demonstrated that DDT is an effective insecticide for the control of the squash borer, *Melittia cucurbitae* (Harr.). It has also been shown in various tests for controlling the squash borer, squash bug, cucumber beetles, and the pickle worm on squash and pumpkin that foliage may be injured and yields reduced following the application of DDT. In table 1 is presented a compilation of these published reports of the phytotoxicity of DDT dusts to squash and pumpkin, arranged in relation to the botanical species[2] and commercial variety used. Although these reports are variable, there appear to be differences in susceptibility to DDT injury between the plant varieties used and between the plant species *Cucurbita maxima* and *C. pepo*.

At Geneva, New York, the first test of DDT on squash in relation to borer control and plant injury was made by the junior author in 1944. A 2 per cent DDT dust was used in comparison with a 1 per cent rotenone dust and a 1 to 200 nicotine sulfate spray. Five successive treatments were made at weekly intervals, starting June 27, 1944. The results are summarized in table 2 and corroborate the information assembled in table 1.

Two per cent DDT dust, when used on Blue Hubbard squash, *Cucurbita maxima*, gave a high degree of borer control but adversely affected the yield as measured by the number and weight of fruits harvested. Although borer infestation records were not taken from the plots of Table Queen squash, *C. pepo*, the yield of this variety was even more adversely affected by the use of 2 per cent DDT

[1] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 695, January 20, 1947.

[2] A pertinent discussion of the botanical characteristics of squashes and pumpkins is given by Thompson (1940).

Table 1.—Phytotoxicity of DDT dusts in relation to botanical species and commercial varieties of squash and pumpkin. A compilation from published reports.

Variety	Per Cent DDT in Dusts Used	Result	Reported by
		A. Varieties belonging to *Cucurbita maxima:*	
Banana	10	no injury	White, 1946
Buttercup	1	no foliage injury	Bruce & Tauber, 1945
	3	no foliage injury	Bruce & Tauber, 1945
	10	foliage injury, later outgrown	White, 1946
Hubbard	1	no foliage injury	Bruce & Tauber, 1945
	3	no foliage injury	Bruce & Tauber, 1945
	3	yield reduced	N. J. Expt. Sta., 1945
	3	plants stunted, but less than acorn (below)	Tate, *et al.*, 1945
	10	foliage injury, later outgrown	White, 1946
		B. Varieties belonging to *Cucurbita pepo:*	
Acorn	3	foliage stunted and chlorotic	Bruce & Tauber, 1945
	3	severe plant injury	N. J. Expt. Sta., 1945
	3	young plants severely stunted	Tate, *et al.*, 1945
Cocozelle	2	plants stunted, harvest delayed, yield reduced	White, 1946
Kentucky field pumpkin	10	foliage injury, later outgrown	White, 1946
Scallop (Patty pan)	3	increased plant growth	Parker, 1945
Small Sugar Pumpkin	3	young plants severely stunted	Tate, *et al.*, 1945
Table Queen	10	foliage injury, later outgrown	White, 1946
Yellow Summer	2	plants stunted, harvest delayed, yield reduced	White, 1946
	2.5	foliage not visibly injured, but yield reduced	White, 1946
	3	increased plant growth	Parker, 1945
	10	severe injury at Beltsville, Md.	White, 1946
	10	foliage injury, later outgrown, at Madison, Wis.	White, 1946
Zucchini	3	increased plant growth	Parker, 1945

Table 2.—Performance of insecticides used for squash borer control, Geneva, N. Y., 1944.

	Squash Variety Used							
	Blue Hubbard (*Cucurbita maxima*)				Table Queen (*C. pepo*)			
	Insecticides Used							
	None	1 Per Cent Rotenone Dust	Nicotine Sulfate Spray 1 to 200	2 Per Cent DDT Dust	None	1 Per Cent Rotenone	Nicotine Sulfate Spray 1 to 200	2 Per Cent DDT Dust
Total number of plants (4 replicates	93	91	94	82	86	79	65	66
Borers found	135	7	30	0	—	—	—	—
Average borers per plant	1.45	0.07	0.31	0.00	—	—	—	—
Total fruits harvested	54	93	80	70	159	187	130	106
Total weight fruits harvested (pounds)	283.0	599.5	481.0	380.5	129.0	169.0	119.0	87.5
Average weight (in pounds), fruits per plant	3.04	6.58	5.11	4.64	1.50	2.13	1.83	1.32

dust than was Blue Hubbard, particularly when compared with the yields from plots dusted with 1 per cent rotenone. Early foliage stunting was particularly noticeable in plots of Table Queen squash which had been dusted with 2 per cent DDT (Fig. 1). Similar confirmatory tests conducted during 1945 were completely nullified by a poor stand of squash and a very low borer infestation.

In 1946 a further study was made of the possibility of differential varietal susceptibilty of squash and pumpkin to DDT injury. For this purpose nine varieties of actual or potential commercial importance in New York, representing three plant species, were used. These varieties and species are shown in table 3. To study more accurately the causes of DDT injury to squash, 3 per cent dusts were made from 50 per cent concentrates of two grades of DDT having setting points[1] of 90°C., and 103-105° C., respectively. The former was similar in setting point to that of the technical grade of DDT commonly used in the preparation of agricultural insecticides. The latter approached, but did not equal, the setting point of "aerosol grade" DDT. For further comparison, dusts containing 1 per cent rotenone, 40 per cent *Ryanex* (from ground stem of *Ryania speciosa*), and 3 per cent di (methoxyphenyl) trichloroethane were included in the 1946 test. All dusts were prepared using talc (*EMTCO* 23) as the diluent.

There were five replicates for each dust treatment and for the untreated check plots for each of the nine squash and pumpkin varieties grown. Individual plots consisted of three hills, each containing three plants when set out. The plants were grown in the greenhouse from seed sown in pots and were set out in the field on June 7, 1946. Six dust applications using the materials mentioned above,

FIG. 1.—Effects of dusts used in 1944 on plants of Table Queen squash. Top: plant dusted with 1 per cent rotenone. Bottom: plant dusted with 2 per cent DDT.

[1] "Setting point" refers to the temperature at which a substance crystallizes from the molten condition and is a more precise measurement than melting point for most commercial grades of DDT, which usually melt over a range rather than at a specific temperature.

FIG. 2.—Effects of DDT dusts used in 1946 on foliage of Delicata squash. Top: untreated plant. Center: plant dusted with 3 per cent DDT, setting point 103–5. C. Bottom: plant dusted with 3 per cent DDT, setting point 90° C.

were made on June 12, 21, and 28, and on July 5, 12, and 19, 1946, using a bellows-type knapsack duster. The first of these applications was directed primarily toward the control of cucumber beetles and was probably not essential for squash borer control. In addition, all plants were dusted on June 8 for beetle control. The check plants received talc and the others received 10 per cent calcium arsenate. Cucumber beetle infestations on the squash plants were relatively low after late June, relatively few squash bugs were present, and almost no wilt was observed in the experimental plots during the summer of 1946. Squash borer infestations were of only moderate severity, being heavier than those of 1945 but lighter than those of 1944. Fruits were harvested in late September and early October, except for the varieties Yankee Hybrid and Cocozelle, which were systematically harvested at weekly intervals starting July 23.

FOLIAGE INJURY.—On July 13, 1946, at a time just before the vines had begun to run appreciably, all plants of all varieties were carefully examined for evidences of insecticidal injury. The observations made are summarized in table 3, section A. The only materials which produced perceptible foliage injury were 3 per cent DDT, setting point 90° C., and 3 per cent di (methoxyphenyl) trichloroethane. The DDT produced no apparent injury to the three varieties belonging to the species *Cucurbita maxima* although varieties belonging to *C. pepo* and *C. moschata* were moderately to severely injured. The injury usually existed in the form of retarded plant development although chlorotic symptoms were present on some plants of the Delicata variety, *C. pepo*. In mid-July representative 3-plant hills of this variety were 2 feet in diameter and one foot high in the untreated plots and in the plots dusted with 3 per cent DDT, setting point 103-105° C. At this time Delicata hills dusted with 3 per cent DDT, setting point 90° C. averaged 10–12 inches in diameter and 5 inches high. (Fig. 2) With the exception of the plants of this variety, most plants showing retarded foliage development following dust applications of 3 per cent DDT of 90° C. setting point appeared to have outgrown the injury within 2 to 3 weeks after dust applications ceased. No apparent foliage injury was observed on any plants dusted with 3 per cent DDT, setting point 103-105° C.

Plants dusted with 3 per cent di (methoxyphenyl) trichloroethane showed variable foliage symptoms, less severe in character than those above, which disappeared in most cases soon after dust treatments ceased. The most common symptom was a light but coarse rugosity of the foliage suggestive of grained leather. In more extreme cases the symptoms resembled those found on plants affected with mosaic. Figure 3 shows a series of leaves of Dickinson pumpkin,

Cucurbita pepo, showing the general range of symptoms produced. The more extreme, rosette-type, symptoms usually appeared on newly developing leaves located on incipient runners which, in most cases, had not been present when the treated plots both indicated a random variability associated with low insect populations. When the records from all nine varieties are considered it appears that the two 3 per cent DDT dusts were of about equal effectiveness in controlling

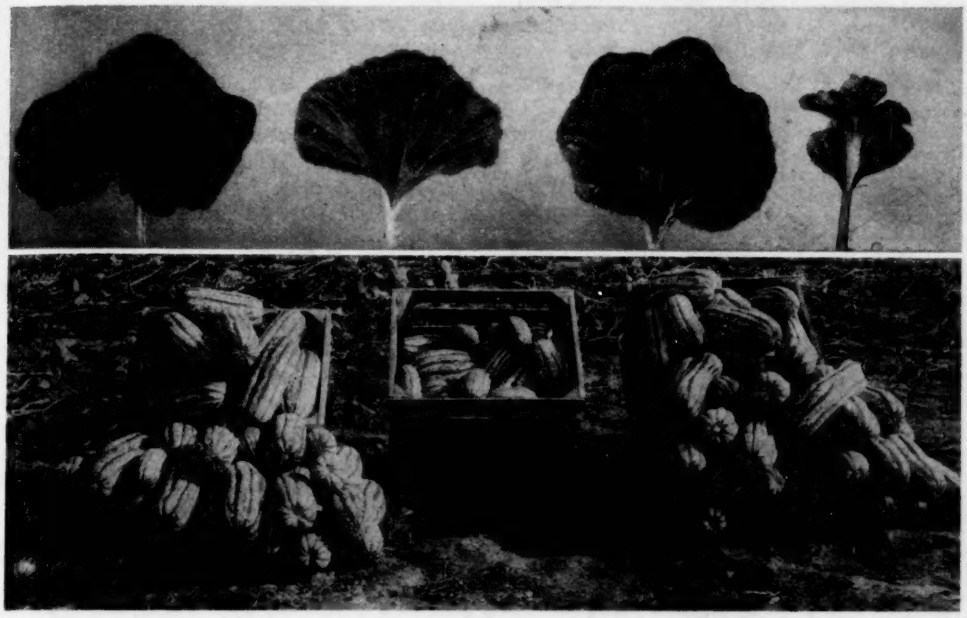

FIG. 3 (above).—Symptoms produced by 3 per cent di (methoxyphenyl) trichloroethane dust on foliage of Dickinson pumpkin in 1946. Normal leaf on left.

(below).—Effects of DDT dusts used in 1946 on yield of Delicata squash. At each crate is shown the actual harvest from 5 replicated plots. *Left:* untreated, 134.5 lbs. (higher than normal because of low squash borer infestations). *Center:* dusted with 3 per cent DDT, setting point 90° C., 34.5 lbs. *Bottom:* dusted with 3 per cent DDT, setting point 103–5° C., 135.5 lbs.

insecticidal dusts were applied. The dust used was prepared from a 50 per cent, technical-grade concentrate of di (methoxyphenyl) trichloroethane supplied by the manufacturer from pilot plant production. It is not known whether the symptoms described may have been due to the chemical itself or to impurities which may have been present.

BORER INFESTATIONS.—Records of squash borer infestations were made at the time of harvest and are summarized in table 3, section B. Plants were considered infested if they contained actual borers or showed evidence of having been infested. The infestations in the untreated plots were relatively low, in no case affecting more than 38.1 per cent of the plants present. Infestations in treated and untreated plots both indicated a random variability associated with low insect populations. When the records from all nine varieties are considered it appears that the two 3 per cent DDT dusts were of about equal effectiveness in controlling the squash borer and were both somewhat more effective than the three other dust mixtures used. These three latter dusts appeared to be of approximately equal effectiveness. Infestations in untreated plots were extremely low in three of the varieties, indicating a possibility of varietal resistance which should be verified under heavier infestations than were present in 1946. Two of these varieties, Dickinson pumpkin and Butternut, had characteristically small, compact, and hard vine stems which appeared less suitable for borer penetration than the stems of the other varieties grown.

EFFECTS ON YIELD.—Yield records, expressed in terms of pounds of fruit harvested per plant, and in numbers of fruits harvested, are summarized in table

Table 3.—Performance of insecticides used for squash borer control, Geneva, N. Y., 1946.

Variety	Species[1]	Insecticide Used					
					3 Per Cent DDT[4]		
		Untreated	Rotenone[2] 1 Per Cent	Ryanex[3] 40 Per Cent	Setting Point 90° C.	Setting Point 103–5° C.	"Methoxy"[5]
A.—*Extent of foliage stunting, July 13, 1946*							
Blue Hubbard	*mx.*	none	none	none	none	none	slight
Boston Marrow	*mx.*	none	none	none	none	none	moderate
Golden Delicious	*mx.*	none	none	none	none	none	moderate
Cocozelle	*pe.*	none	none	none	moderate	none	slight
Yankee Hybrid	*pe.*	none	none	none	moderate	none	none
Delicata	*pe.*	none	none	none	severe	none	none
Conn. Field Pumpkin	*pe.*	none	none	none	moderate	none	slight
Dickinson Pumpkin	*pe.*	none	none	none	severe	none	moderate
Butternut	*mo.*	none	none	none	severe	none	moderate
B.—*Per cent of plants infested with squash borers*							
Blue Hubbard	*mx.*	27.8	9.1	4.4	0.0	2.2	7.5
Boston Marrow	*mx.*	19.0	11.6	4.5	2.2	0.0	11.4
Golden Delicious	*mx.*	31.7	11.4	11.1	9.5	0.0	7.5
Cocozelle	*pe.*	2.9	2.4	0.0	0.0	7.5	7.3
Yankee Hybrid	*pe.*	23.8	2.2	14.3	2.5	0.0	5.3
Delicata	*pe.*	28.9	8.9	8.9	0.0	0.0	2.3
Conn. Field Pumpkin	*pe.*	38.1	7.0	8.9	2.3	0.0	6.7
Dickinson Pumpkin	*pe.*	5.0	0.0	0.0	0.0	0.0	0.0
Butternut	*mo.*	0.0	0.0	0.0	0.0	0.0	2.9
C.—*Average yield of fruit in pounds per plant*							
Blue Hubbard	*mx.*	5.6	5.9	5.2	7.0	4.7	6.4
Boston Marrow	*mx.*	6.9	5.9	6.7	6.3	7.6	5.7
Golden Delicious	*mx.*	5.0	5.9	5.6	5.2	5.6	5.6
Cocozelle	*pe.*	7.3	5.9	7.1	5.5	6.8	7.0
Yankee Hybrid	*pe.*	6.6	5.9	7.0	4.1	5.8	4.4
Delicata	*pe.*	3.0	2.7	3.3	1.1	3.0	3.1
Conn. Field Pumpkin	*pe.*	15.2	20.8	20.3	15.5	16.3	18.4
Dickinson Pumpkin	*pe.*	17.8	15.0	12.8	9.6	14.6	16.6
Butternut	*mo.*	5.5	4.9	5.9	4.2	4.2	3.9
D.—*Number of fruits harvested*							
Blue Hubbard	*mx.*	21	34	30	31	31	36
Boston Marrow	*mx.*	44	39	43	42	47	35
Golden Delicious	*mx.*	39	42	42	46	47	43
Cocozelle	*pe.*	107	110	135	88	116	129
Yankee Hybrid	*pe.*	159	162	167	101	153	113
Delicata	*pe.*	72	68	78	34	76	79
Conn. Field Pumpkin	*pe.*	35	46	47	34	47	57
Dickinson Pumpkin	*pe.*	49	43	34	36	37	44
Butternut	*mo.*	57	42	67	68	49	56

[1] The following species were used in this experiment: *mx.*: *Cucurbita maxima* Duchesne; *pe.*: *Cucurbita pepo L.*; *mo.*: *Cucurbita moschata* Duchesne.
[2] Furnished by Cooperative G. L. F. Soil Building Service, Inc., Ithaca, N. Y.
[3] Furnished by Merck & Co., Inc., Rahway, N. J.
[4] Furnished by E. I. du Pont de Nemours & Co. (Inc.), Wilmington, Delaware.
[5] di (methoxyphenyl) trichloroethane, furnished by Niagara Sprayer and Chemical Corp., Middleport, N. Y.

3, sections C and D. Yields froms untreated plots were not appreciably reduced by the low borer infestations of 1946 and the records given serve principally, therefore, as a preliminary indication, subject to further verification, of the effect of the various dusts upon the yields of the plant varieties used in 1946.

The three varieties belonging to *Cucurbita maxima* (Blue Hubbard, Boston Marrow, Golden Delicious) showed no apparent effect on yields as a result of any dusts used in 1946, including even those containing DDT. This differs from the 1944 results, shown in table 2, where the yield of Blue Hubbard plots treated with 2 per cent DDT dust was definitely lower than in plots dusted with 1 per cent rote-

none or sprayed with 1 to 200 nicotine sulfate. It is not known whether the difference between the 1944 and 1946 results is due to a possible superiority in the type of DDT used in 1946, particularly that having the 90° C. setting point, or to other factors.

Yields of varieties belonging to *Cucurbita pepo* (Cocozelle, Yankee Hybrid, Delicata, Connecticut Field Pumpkin, Dickinson Pumpkin) showed, except for Connecticut Field Pumpkin, a definite reduction in plots treated with 3 per cent DDT, setting point 90° C. Plots of this species dusted with 3 per cent DDT, setting point 103-105° C., showed no similar, clearly defined yield reductions except, possibly, in the case of Dickinson Pumpkin.

Plots of Butternut squash, the sole representative of *C. moschata*, gave variable yields when treated with the different dust mixtures but indicated possibly significant reductions in total weights of fruits harvested following the use of both grades of 3 per cent DDT dusts.

Yield reductions following the use of 3 per cent di (methoxyphenyl) trichloroethane dust were not apparent except in plots of Yankee Hybrid and, possibly, those of Butternut.

SUMMARY.—Tests made at Geneva, N. Y., in 1944 and 1946 confirm published reports of the effectiveness of DDT for controlling the squash borer and of possible differences between varieties of squashes and pumpkins in susceptibility to DDT phytotoxicity. Tests in 1946 show that much of the observed foliage injury and yield reduction produced by DDT dusts is associated with the setting point of the DDT used. Three per cent dusts prepared from DDT having a setting point of 90° C. were more injurious than similar dusts prepared from DDT having a setting point of 103-105° C. Nine varieties of squashes and pumpkins, representing 3 botanical species, were used in the 1946 tests. Squashes of the Hubbard type, belonging to the species *Cucurbita maxima*, were apparently not injured by 3 per cent dusts made from either of the two grades of DDT used in 1946, although moderate yield reduction occurred in Blue Hubbard plots treated in 1944 with a 2 per cent dust made from a then available technical grade of DDT. The most severe foliage injury and yield reduction occurred on squash and pumpkin varieties belonging to the species *Cucurbita pepo* following treatments with a 3 per cent dust prepared from DDT having a setting point of 90° C. Connecticut Field Pumpkin was the only tested variety of this species which showed no such adverse effect on yield. Almost no foliage injury or yield reduction occurred when these varieties were similarly treated with 3 per cent dust prepared from DDT having a setting point of 103-5° C. Butternut squash, representing the species *C. moschata*, responded similarly, as regards foliage injury and yield reduction, to most tested varieties of *C. pepo*. In 1946 no phytotoxic effects were observed on plants of any variety dusted with 1 per cent rotenone or 40 per cent *Ryanex*. Plants dusted with 3 per cent di (methosyphenyl) trichloroethane developed rugose foliage symptoms which usually disappeared after treatments ceased and which apparently affected the yield of but 2 of the 9 varieties tested.

Extremely low squash borer infestations on plants of Dickinson pumpkin and Butternut squash indicated a possible varietal resistance to this insect.

LITERATURE CITED

Bruce, W. N., and O. E. Tauber. 1945. Trials with DDT on potatoes, cabbage, and squash. JOUR. ECON ENT. 38(4): 439–41.

New Jersey Agr. Experiment Sta. 1945. Experiments with DDT conducted by state agricultural-experiment stations . . . *et al.* U.S.D.A., B. E. & P. Q. E-664s.

Parker, R. L. 1945. Experiments with DDT conducted by state agricultural experiment stations . . . *et al.* U.S.D.A. B. E. & P. Q. E-644r.

Tate, H. D., R. E. Hill, and D. B. Gates. 1945. Experiments with DDT conducted by state agricul tural experiment stations . . . *et al.* U.S.D.A. B. E. & P. Q. E-644e.

Thompson, R. C. 1940. Production of pumpkins and squashes. U.S.D.A. Leaflet 141.

White, W. H. 1946. Summary of results with DDT against truck crop, tobacco, and sugar beet insects. U.S.D.A. B. E. & P. Q. E-692.

Hexaethyl Tetraphosphate as an Insecticide[1]

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Hexaethyl tetraphosphate is the active ingredient of an insecticide developed by the Germans during the war to which they gave the name *Bladan* (Hall 1945, Kilgore 1945, and Smadel & Curtis 1945). It is an oily, somewhat viscous liquid having a specific gravity of 1.28; is miscible in water and in many of the common organic solvents, but is not soluble in petroleum solvents such as kerosene and petroleum ether. It is readily hydrolyzed by water with loss in insecticidal potency; hence it must be applied as a freshly prepared solution.

Hexaethyl tetraphosphate was prepared in the laboratory[2], by two methods one of which has been patented by Schrader (1942, 1943) and the other by Woodstock (1946).

Preliminary small-scale laboratory studies were made during 1946 to evaluate the approximate toxicity of hexaethyl tetraphosphate to the codling moth, *Carpocapsa pomonella* (L.), several species of aphids, and the two-spotted mite, *Tetranychus bimaculatus* Harvey.

The experiments reported in this paper do not include a consideration of the effect this material may have on the sprayman, on spray machinery, or on host plants except for limited spray tests of hexaethyl tetraphosphate (0.1 per cent) plus *Dreft* (sodium lauryl sulfate, 0.05 per cent) on potted lima bean plants and chrysanthemum plants, on which no injury resulted.

Tests with the Codling Moth.—In tests with the codling moth the apple-plug method was employed. In each test about 100 plugs were sprayed with a water solution of the compound. In most of the tests the solution was freshly prepared. A single ready-to-hatch codling moth egg was used to infest each plug, usually within a few hours after spraying. None of the plugs was stung, and the percentages of wormy plugs obtained with various concentrations of hexaethyl tetraphosphate are given below.

Pounds per 100 Gallons	*Per Cent*
Schrader method:	
4 (Commercial)[1]	0
1 Fresh	0
1 12 days old	86
1 Plugs infested 3 days after spraying	72
0.5	7
0.25	50
Woodstock method:	
0.5	2
	3

[1] Prepared on a plant scale.

As shown by the data obtained, hexaethyl tetraphosphate made by either the Schrader or by the Woodstock method is a toxic contact spray for newly hatched codling moth larvae when freshly diluted and applied at concentrations of 1 pound and 0.5 pound per 100 gallons. However, since this compound is soluble in water and hydrolyzes to comparatively nontoxic compounds in water solution, it does not have the residual effectiveness required for the practical control of the codling moth. There was no significant difference in the insecticidal potencies of the hexaethyl tetraphosphate prepared by the two methods.

Tests Against Aphids.—Hexaethyl tetraphosphate was tested against aphids by spraying infested shoots and by means of the leaf-disk technique developed for acaricidal tests as described by Siegler (1947).

In the spray tests, infested shoots cut from the host plant were placed in a bottle of water and then, as they revolved on a turntable in a spray tower, were sprayed with a nasal atomizer held about 30 inches from the aphids. In each test 20 ml. of spray solution was discharged in the form of a fine mist under a pressure of 40 pounds. Applications were usually made within an hour after the solution was prepared, although in one test against the aphid on *Helianthus* the solution was allowed to stand at room temperature (25 to 30° C.) for 1 day before use. Test aphids included the apple aphid, *Aphis pomi* Deg., the chrysanthemum aphid, *Macrosiphoniella sanborni* (Gill.), and species on helianthus, *Macrosiphum ambrosiae* (Thos.).

[1] Eastern Branch Program.
[2] At the Agricultural Research Center, Beltsville, Md.

The hexaethyl tetraphosphate was tested in two strengths, 0.1 and 0.5 per cent, in comparison with nicotine (from nicotine sulfate) at 0.05 per cent. To each solution *Dreft*, 0.05 per cent, was added as a wetting agent. The results, which are given in table 1, show that freshly prepared solutions of hexaethyl tetraphosphate were highly effective against all test species, whereas those that stood for 1 day before use lost much of their effectiveness.

Table 1.—Percentage mortality of aphids sprayed with hexaethyl tetraphosphate and with nicotine.

Material and Concentration[1] (Percentage by Weight in Water)	Chrysanthemum Aphid	Apple Aphid	Aphid on *Helianthus*	
			Fresh solution	1-Day old solution
Haexaethyl tetraphosphate:				
0.1	100	96	99	69
.05			100	24
Nicotine (from nicotine sulfate)				
.05	87	99		
Checks:				
Dreft 0.05	0	13		
Water	0	0	12	
			2	

[1] *Dreft*, 0.05 per cent, was used as a wetting agent in all tests except the water check.

In the tests by the leaf-disk technique, five infested leaf disks were immersed, one at a time for 3 seconds, in the solution. Test aphids on kale included the cabbage aphid, *Brevicoryne brassicae* (L.), and the green peach aphid, *Myzus persicae* (Sulz.) and those on squash included the melon aphid, *Aphis gossypii* Glov., the green peach aphid, and the potato aphid, *Macrosiphum solanifolii* (Ashm.)

The hexaethyl tetraphosphate was tested in three strengths, 0.1, 0.05, and 0.025 per cent. As in the previous test, *Dreft*, 0.05 per cent, was added. The results obtained are given in table 2. Hexaethyl tetraphosphate, 0.1 per cent, gave complete kills of all the test aphids; concentrations of 0.05 and 0.025 per cent of hexaethyl tetraphosphate also gave complete kills of the aphids on squash, but only incomplete kills of those on kale.

Tests Against Mites.—The leaf-disk technique was also used in tests of hexaethyl tetraphosphate against the two-spotted mite, *Tetranychus bimaculatus*. Five infested bean-leaf disks were used in each test. The hexaethyl tetraphosphate was tested alone at two strengths, 0.1 and 0.05 per cent, and in combination with *Dreft*, 0.05 per cent, at three strengths, 0.1, 0.05, and 0.025 per cent. Applications were made with freshly prepared solutions but in two tests the preparations were also allowed to stand for 1 day before use. The data obtained are given in table 3. The solutions of hexaethyl tetraphosphate freshly prepared and applied at concentrations of 0.05 per cent and 0.1 per cent, alone or combined with *Dreft*, were very effective against the nymphs and adults of this species as was 0.025 per cent of the compound combined with *Dreft*. The solutions containing *Dreft* lost their effectiveness after aging for 1 day.

Table 2.—Percentage mortality of aphids treated with hexaethyl tetraphosphate plus *Dreft*, 0.05 per cent.

Concentration (Percentage by Weight in Water)	On Kale	On Squash
0.10	100	100
.05	86	100
.025	47	100
Checks:		
Dreft .05	5	5
Water	5	29

Table 3.—Percentage mortality of hexaethyl tetraphosphate, alone and with *Dreft* 0.05 per cent, to nymphs and adults of the two-spotted mite on lima beans.

Concentration (Per Cent by Weight in Water)		Freshly Prepared Solutions	1-Day Old Solutions
0.10		97	
.05		90	
.10	With *Dreft*	100	32
.05	With *Dreft*	98	40
.025	With *Dreft*	97	
Checks:			
Dreft		12	34
Water		0.3	4

Conclusions.—The results of small-scale laboratory experiments indicate that hexaethyl tetraphosphate is highly toxic to newly hatched codling moth larvae, to several species of aphids, and to the two-spotted mite. Tests on a larger scale under field conditions are needed to determine whether this compound possesses practical value as an insecticide.—11-21-46

LITERATURE CITED

Hall, S. A. 1945. Insecticides, insect repellents, rodenticides, and fungicides of I. G. Farbenindustrie A. G., Elberfeld and Leverkusen, Germany. U. S. Dept. Com. Off. Pub. Bd. Rpt. No. 252.

Kilgore, L. B. 1945. New German insecticides. Soap and Sanit. Chem. 21(12): 138–9; 169, 171.

Kilgore, L. B. 1945. Investigation of insecticide and insectifuge research in western Germany. U. S. Dept. Com. Off. Pub. Bd. Rpt. No. 22413.

Schrader, G. 1942. Hexaalkyl and hexacycloalkyl esters of tetraphosphoric acid. German Patent No. 720,577, issued April 9, 1942; assigned to I. G. Farbenindustrie A.-G. (Abstract in Chem. Abs. 37: 2388 (1943)).

Schrader, G. 1943. Hexaesters of tetraphosphoric acid. U. S. Pat. 2,336,302, issued Dec. 7, 1943; vested in the Alien Property Custodian.

Siegler, E. H 1946. Leaf-disk technique for laboratory acaricidal tests. JOUR. ECON. ENT. 40(2): 280.

Smadel, J. E., and F. J. Curtis. 1945. Manufacture of insecticides, insect repellents, rodenticides. I. G. Farbenindustrie A.-G., Leverkusen and Elberfeld. U. S. Dept. Com. Off. Pub. Bd. Rpt. No. 240.

Woodstock, W. H. 1946. Method of producing neutral esters of molecularly dehydrated phosphoric acids. U. S. Pat. 2,402,703, issued June 25, 1946; assigned to Victor Chemical Works.

Benzene Hexachloride and Wireworm Control

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One of the major obstacles to practical wireworm control in the potato industry of Connecticut has been the lack of an effective insecticide which could be applied easily and cheaply. The soils of the commercial potato acreage are not physically suited to the practical application of liquid insecticides, such as those currently being put on by power applicators, nor are the cash returns from potatoes sufficient to warrant too great a cost in this respect. Results obtained from preliminary laboratory and field studies on the use of hexachlorocyclohexane indicate that it is an effective insecticide for wireworms and holds promise of overcoming many of the objectionable factors which heretofore have made commercial control impractical.

The principal objectives in these studies have been (1) the concentration of insecticide most effective under field conditions, (2) the method or methods most suitable for practical application and (3) the relationship of the amount applied or the method of application used to the taste of tubers grown in treated soils. The dosages for soil treatment refer to pounds per acre of crude hexachlorocyclohexane in which the gamma isomer was 10 per cent. All soil applications were made with dilute dusts in which pyrophyllite was used as the diluent.

The methods of application studied during the 1946 season included broadcast treatment, row treatment, seedpiece treatment and poison baits. The dosage series for both the broadcast and the row treatments was highly exploratory and was designed to include concentrations of hexachlorocyclohexane greater than and less than a predetermined level of one pound of crude material per acre. Preliminary work indicated that one pound per acre, if thoroughly mixed with soil, is sufficient to produce 100 per cent mortality of wireworms. No attempt was made to regulate the deposit on treated seed pieces and the poison bait was of the order 1 to 1000, benzene hexachloride to wheat, by weight.

BROADCAST TREATMENT.—The fields selected for the broadcast treatment plots were first plowed and disc-harrowed. The dilute hexachlorocyclohexane dusts were then applied with a grain drill which had previously been calibrated to deliver known amounts and the plots were disc-harrowed once each way to mix together the soil and insecticide to a depth of 5 or 6 inches. The plots were continuous strips through the fields and were approximately one third of an acre in area.

The method used in scoring all the tuber samples in these studies was based upon the standards set forth for potatoes in the U. S. No. 1 grade. The accepted tolerance for defects allows for not more than 6 per cent, by weight, of the tubers being below the requirements of the grade. Since the greater part of tubers thrown out of grade U. S. No. 1 in Con-

necticut are below grade requirements because of wireworm injury, the results from any given treatment can best be measured against the 6 per cent tolerance for defects. Each tuber was brushed to determine the per cent free from injury. All injured tubers were reexamined to determine the extent of injury. The values expressed as the percentages out of grade U. S. 1 reflect the degree of practical control obtained and the ease with which tubers of similar quality can make grade. The legal tolerances are based on weight but it is believed that the percentages expressed in these tables though on a number basis, are closely comparable

Because of the risk of tuber contamination from benzene hexachloride, the scope of this test was limited. The plots for treatments 1, 2 and 3 were in triplicate and in treatment 4 they were in duplicate only. Treatment 2 received 65 pounds of 1 per cent dust per acre, treatment 3 received 65 pounds of 3 per cent dust per acre and treatment 4 received 100 pounds of 5 per cent dust per acre. The tuber samples were drawn at random from three points within each plot and consisted of all tubers greater than 1.5 inches in diameter in those sampling areas.

Table 1 indicates the relative field efficiency of the three levels of concentration employed. Under the conditions of this experiment, considering the method of application used, the seriousness of the infestation and the light sandy soil on which the potatoes were grown, two pounds per acre of crude benzene hexachloride, or 0.2 pound of the gamma isomer, resulted in commercially clean potatoes. Heavier applications do not appear to reach that portion of the wireworm population which apparently remains unaffected by the insecticide when applied in this manner. The reduction in percentage of out of grade tubers attributable to 0.65 pounds per acre of the crude poison is not sufficient to place it in a class with the higher dosages but the degree of injury is considerably less than that in the check plots.

Table 1.—Broadcast-Wetstone Lot 7.

Lbs. per Acre[1]	Tubers in Sample	Per Cent Injured	Per Cent Out of Grade U. S. 1
1.—Check	818	78.6	53.4
2.—0.65	539	39.4	31.8
3.—2.0	559	9.3	3.9
4.—5.0	275	12.0	4.0

[1] Crude benzene hexachloride.

Table 2.—Broadcast-Wetstone Lot 6.

Lbs. per Acre Crude Poison[1]	Tubers in Sample	Per Cent Injured	Per Cent Out of Grade U. S. 1
1.—Check	675	70.5	46.4
2.—0.65	560	33.7	17.5
3.—2.50	643	8.4	2.5

[1] Benzene Hexachloride.

The field arrangement for this test consisted of only one one-third acre plot for each treatment but random sampling was replicated three times within each plot. The principal point of interest here was to approach the dosage of approximately 2 pounds crude poison per acre but to apply it in a greater quantity of a more dilute dust in order to study the factor of distribution throughout the soil. Treatment 2 received 65 pounds of 1 per cent dust and treatment 3 received 250 pounds of 1 per cent dust.

Two and one-half pounds per acre of the crude material applied in 250 pounds of dust produced commercially clean potatoes but did not improve on the control given by 2 pounds of crude material applied in 65 pounds of dust as shown in table 1. The application of 0.65 pound per acre resulted in a lower "out of grade" percentage than in the check, and also lower than the same treatment on Lot 6 previously shown, but did not result in commercial control.

It appears evident from these data that 2 to 2.5 pounds of crude benzene hexachloride per acre, applied broadcast in the form of a dilute dust, will result in practical, effective wireworm control. There are, undoubtedly, many factors of soil texture and physical condition which can modify the results but such were not encountered this year.

ROW TREATMENT.—All row treatment studies were conducted on a 1 acre portion of a field of potatoes, within which the treatments were replicated four times in a randomized block. The individual replicates were four rows wide and the tuber samples were collected from the center

portion of the two inner rows. The rows were opened, and the fertilizer banded, by a planter with the covering discs removed. The dusts were applied by means of a rotary type hand duster and the Benzene Hexachloride concentrations were determined from the strength and amount of dust applied. The seed pieces were dropped, and the rows covered by hand.

Table 3.—Benzene Hexachloride treatments, Liebman Lot-Melrose.

Lbs. per Acre	Tubers in Sample	Per Cent Injured	Per Cent Out of Grade U. S. 1
1.—Check	1895	71.4	51.2
2.—0.33	655	38.5	15.0
3.—0.66	452	32.3	11.5
4.—1.32	639	8.6	2.3
5.—1.50	611	5.0	0.5
6.—3.00	640	5.3	0.8
7.—4.50	727	5.1	0.8

The material for treatments 2, 3 and 4 was applied in 1 per cent dust and for treatments 5, 6 and 7 in 5 per cent dust.

The dosage range used in this test is shown in table 3. In spite of the relatively high percentage of tubers out of grade in treatments 2 and 3, there was a remarkably good reduction in the degree of injury in comparison with the check so that on any other field but this one, which is considered to be as seriously infested as any field in the state, the concentrations of 0.33 and 0.66 pounds of crude benzene hexachloride per acre might be expected to give commercial control of a reasonably high order. All treatments containing at least 1.32 pounds per acre of crude material gave very good commercial control. In fact, out of a total of 2078 tubers examined from these plots, all but 14 were in grade. In contrast to this, 970 tubers out of 1895 examined from the check plots were seriously out of grade, exceeding in injury the tolerance set up for the grade U. S. Commercial which allows for 20 per cent of the tubers to be below grade requirements.

The row treatment method of application appears to leave a small percentage of the wireworm population unaffected by the insecticide. Since the material is applied to a restricted area and depends for its success upon the movement of the larvae to the hills for the initial feeding

Table 4.—Liebman Lot-Melrose.

No.	Seed Piece Treatment	Tubers in Sample	Per Cent Injured	Per Cent Out of Grade U. S. 1
1.—Check		1895	71.4	51.2
2.—HCH Dust		659	48.3	23.1
3.—HCH Dip		654	42.2	19.4
4.—DDT Dip		662	78.7	61.8

period on the seed pieces, it seems likely that those larvae not affected represent that portion of the population that does not feed to any degree on the seed pieces. Row treatment, in general, appears to be a more effective method of application than broadcast but, as tests so far indicate, there is less freedom with respect to tubers taking up the taste of benzene hexachloride.

SEED PIECE TREATMENT.—The methods employed in this study for the treatment of seed consisted of dusting the seed with a 50 per cent wettable concentrate or dipping the seed in a water suspension made from 50 per cent wettable concentrate. The value of this method of treatment was the principal objective here and no attempt was made to determine the deposit on the seed piece.

The degree of control obtained by this method of application falls far short of commercial control yet the difference between treatments 2 and 3, containing hexachlorocyclohexane and treatments 1 and 4, not containing this material shows that there is a very pronounced effect on the wireworm population. This is further borne out by the fact that diggings made within 10 days after planting disclosed many dead or dying larvae in the hills of treatments 2 and 3. Many of the seed pieces in these treatments were entirely free of any wireworm feeding indicating that there might be a slight repellent action in this method of application. The plants in treatment 2 were slightly delayed in development during their first month of growth but this effect soon disappeared and the final yields showed no reflection of the retardation.

POISON BAIT (WHEAT).—Previous work with DDT had, in the absence of other more suitable methods of control, shown poison wheat baits to be reasonably effective under some conditions. Baits were therefore prepared to contain benzene

hexachloride 1 to 1000 by weight and were compared with baits containing DDT at 1 to 500 by weight. This necessitated the placement of baits next to the seed pieces, half of which were dusted with lead arsenate to repel the larvae from the seed pieces and to force them to feed on the baits.

Table 5.—Liebman Lot-Melrose.

TREATMENT	TUBERS IN SAMPLE	PER CENT INJURED	PER CENT OUT OF GRADE U. S. 1
1.—Check	1895	71.4	51.2
2.—HCH 1-1000	658	34.0	15.3
3.—DDT 1-500	590	62.7	42.9
4.—HCH 1-1000[1]	742	33.6	17.8
5.—DDT 1-500[1]	685	54.2	37.1

[1] Lead arsenate on seedpieces.

Table 5 indicates the relative effectiveness of benzene hexachloride baits as compared with no treatment and with DDT. Seed piece counts showed many larvae feeding in the benzene hexachloride baits and there was a moderate reduction in injury due to treatment. This method of control may prove practical and effective for other insects but it has no place in a wireworm control program.

EFFECT ON TUBER TASTE.—The study on the relationship of the amount of benzene hexachloride applied and the method of application, to the taste of tubers grown on these soils, has not been completed. Taste tests are being conducted by The Department of Home Economics at the University of Connecticut[1] and, to date, only a few samples have been tested. The preliminary reports received so far indicate that benzene hexachloride applied in the row at 1.5 pounds crude material per acre or broadcast at 2.5 pounds crude material per acre does not contaminate the tubers. In fact, broadcast applications of 7.5 pounds of crude material per acre do no more than impart a slight taste to tubers which are boiled in their skins. Boiled and peeled potatoes or baked potatoes are not affected. The taste, when it is present, is described as medicinal, or earthy.

GENERAL.—The soils on which these tests were made are fine sandy loam in texture with a reaction of pH 5.0. The materials were applied during the first week of May. All attempts to produce mortality through fumigation, *per se*, failed and field observations indicate that there has been no repellency at the dosages employed in these tests.—11-21-46

[1] Under the direction of Dr. Martha Potgieter.

Benzene Hexachloride and Other Compounds for Control of Wireworms Infesting Potatoes[1]

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The eastern field wireworm, *Limonius agonus* (Say), and the wheat wireworm, *Agriotes mancus* (Say), are very destructive pests in New Jersey. Crops especially susceptible to attack include potatoes, cabbage cauliflower, broccoli and many others. The Entomology Department of the New Jersey Agricultural Experiment Station has for a number of years conducted research on control methods for this insect pest. Progress was slow, however, until the advent of benzene hexachloride. This insecticide has shown outstanding results in preliminary field and laboratory tests in New Jersey, and this paper is a report of the work done and the results obtained with benzene hexachloride and certain other materials against wireworms during 1945 and 1946.

MATERIALS USED[3].—The benzene hexachloride (1,2,3,4,5,6-hexachlorocyclohexane) used was supplied by several differ-

[1] These experiments were conducted jointly by the Departments of Entomology and Plant Pathology of the New Jersey Agricultural Experiment Station.

[2] Journal Series paper of the New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.

[3] Benzene hexachloride used in these tests was supplied by the following companies: California Spray-Chemical Corporation, E. I. du Pont de Nemours and Company, Merck and Company, Inc. and the Niagara Sprayer and Chemical Corp. The DDT used was furnished by Sherwin-Williams Company and the "Rhothane" by Rohm and Haas Company.

ent companies, with considerable variation in the gamma isomer content. Standardized mixtures of one per cent gamma isomer content were prepared in a *Messinger* dust mixer, the diluent used being either talc or pyrophyllite. In each case the gamma isomer content used in calculating the dilution was that given by the company supplying the material.

Dichloro-diphenyl-trichloroethane (DDT) and dichloro-diphenyl-dichloroethane (*Rhothane*) were diluted to contain one per cent of the toxic principle in the final mixture. These dusts were prepared with a *Messinger* dust mixer, and the diluent used was either talc or pyrophyllite.

FIELD EXPERIMENTS: *Procedure.*—The field plot test at Perrineville, New Jersey was laid out to consist of duplicated plots, 50 by 50 feet. The insecticides tested in this experiment were benzene hexachloride applied at 2, 3, 5 and 10 pounds of the gamma isomer per acre, dichloro-diphenyl-trichloroethane and dichloro-diphenyl-dichloroethane applied at 25 pounds per acre. These materials were broadcast by hand on the soil surface April 11, 1946, and immediately disked and harrowed into the top soil. The potatoes were planted the same day and were of the Katahdin variety. Observations on the wireworm infestation in the various treatments were made throughout the season. Early season counts were made by digging up and examining seed pieces for wireworm damage in the treated and untreated plots. At harvest time, tubers from representative areas in each plot were examined for wireworm population and injury.

At Freehold, New Jersey, duplicated plots 50 by 50 feet in size were laid out and arranged in a randomized fashion. Materials used in this experiment were benzene hexachloride applied at the rate of 3 and 5 pounds of the gamma isomer per acre. Infestation and yield records were made as outlined above.

The test conducted at Smithburg, New Jersey, was for the purpose of studying the effect of fall treatments on wireworms infesting potatoes. One plot 50 by 50 feet was laid out to receive benzene hexachloride and two adjacent plots 100 by 100 feet were laid out for the application of crude processed naphthalene. Benzene hexachloride was applied broadcast by hand at the rate of 1.6 pounds of the gamma isomer per acre and disked into the soil. Application of these materials was made in November 1945. Potatoes were planted April 4, 1946, and were of the Katahdin variety. Yield records and infestation counts were made as outlined above.

Table 1.—Results of field-plot experiments with benzene hexachloride, DDT, and Rhothane for the control of wireworms infesting potatoes, Perrineville, N. J. 1946.

Treatment, Pounds per Acre	Bushels per Acre*	Number Tubers Examined	Number Tubers Infested	Per Cent Wireworm Control
2 Γ-benzene hexachloride, A	383.9	1619	11	97.8
3 Γ-benzene hexachloride, B	412.5	1751	24	95.2
3 Γ-benzene hexachloride, C	428.8	1815	51	89.8
3.3 Γ-benzene hexachloride, A	386.7	1625	7	98.6
5 Γ-benzene hexachloride, B	407.1	1709	2	99.6
10 Γ-benzene hexachloride, B	310.0	1178	1	100.0
25 DDT	425.4	1794	32	93.6
25 Rhothane	444.2	1878	100	80.1
Check	339.2	1136	502	—

* Harvested August 3, 1946.

Results.—The results obtained in the field test at Perrineville, are shown in table 1, at Freehold, in table 2 and at Smithburg, in table 3.

DISCUSSION OF RESULTS.—The results presented in tables 1, 2 and 3 represent wireworm injury to tubers harvested from a composite sample of 0.02 acre. The benzene hexachloride used in these experiments was said by the suppliers to contain stated amounts of the gamma isomer and on this basis the dilutions were made to give the desired dosages of the gamma isomer per acre. After the experiments were initiated some of the suppliers corrected the original stated analysis. Accordingly, we have made the necessary corrections in the dosage per acre, thereby making the dosages in column one of the tables appear irregular as com-

Table 2.—Results of field plot experiments with benzene hexachloride for the control of wireworms infesting potatoes, Freehold, N. J. 1946.

Treatment, Pounds per Acre	Bushels per Acre*	Number Tubers Examined	Number Tubers Infested	Per Cent Wireworm Control
3 Γ-benzene hexachloride	438.0	2252	20	91.6
5 Γ-benzene hexachloride	403.3	1871	3	98.7
Check	480.0	2505	238	—

* Harvested August 5, 1946.

pared to the original concentrations desired. In planning the experiments the economics of potato production was taken into consideration, therefore a dosage range which would be economically feasible for the grower was selected. Fortunately, this dosage range appears to be more than enough for effective control.

The irregularities in yield are undoubtedly due to unevenness of the soil, and probably to too few replicates; however 10 pounds of gamma isomer showed some retardation of germination, but it should be pointed out that one replicate of this plot was in a low area and no doubt some reduction was due to water damage.

The slight variations in control obtained with the same concentrations of benzene hexachloride were of no particular significance although no doubt there was a slight variation in the gamma isomer content of the different brands of materials used in the experiments. It will be noted that 1.6 pounds in table 3 and 2 and 3 pounds in the other tables gave almost complete protection against tuber injury. This indicates that all the dosages are above the optimum necessary to give commercial control. Most of the injured tubers in these plots would have passed as U.S. No. 1 grade potatoes.

An outstanding result which is not brought out in any of the tables is that

Table 3.—Results of field-plot experiments with benzene hexachloride for the control of wireworms infesting potatoes, Smithburg, N. J. 1946.

Treatment, Pounds per Acre	Bushels per Acre*	Number Tubers		Per Cent Wireworm Control
		Examined	Infested	
1.6 Γ-benzene hexachloride	285.0	1276	8	98.7
Check	268.0	1188	608	—

* Harvested July 29–30, 1946.

the benzene hexachloride treated plots remained green for a considerable period after the untreated plots were completely dead. Observations during the season indicated that leafhopper damage on the benzene hexachloride plots was much less severe than on the check plots. This observation leads the writers to the belief that some substance toxic to the potato leafhopper was taken up by the plants from the benzene hexachloride plots.

EFFECT OF BENZENE HEXACHLORIDE ON WIREWORMS.—Since our results indicated that benzene hexachloride was outstanding for wireworm control when applied to the soil, observations were made on the potato spray and dust plots at harvest to determine the effect of benzene hexachloride on wireworms when applied to the foliage. The benzene hexachloride applied to the potato foliage in the potato spray test was used at a concentration of 0.17 pound of the gamma isomer per 100 gallons of water. Seven applications of the spray were made, beginning on June 11 and ending on July 29. Examination of tubers from the spray plots showed that good control of wireworms was obtained and these results are given in table 4.

Table 4.—Effect of benzene hexachloride applied as a spray to potato plant foliage, on wireworms infesting the tubers, Cranbury, N. J. 1946.

Treatment	Tubers Examined	Tubers Infested
Benzene hexachloride, 7 applications	240	3
Check (7 applications, calcium arsenate-Bordeaux spray)	269	31

Eight dust applications were made on the potato dust experiment at weekly intervals beginning June 8. The dust mixture used contained approximately .45 per cent of the gamma isomer of benzene hexachloride, and was applied at the rate of 30 to 35 pounds per acre. Examination of the tubers in the dust plots indicated they were relatively free of wireworm damage in the plots which received benzene hexachloride, whereas severe wireworm damage was noted in the check plots.

In another experiment, potatoes were dusted with a benzene hexachloride dust containing .75 per cent of the gamma isomer for the control of the potato aphid. Between the application and time of examination of the field for aphid control rain occurred and no doubt some of the dust was washed into the soil. Dead wireworms were found in large numbers on the surface of the soil following the dust treatment.

LABORATORY EXPERIMENTS.—Upon examination of germinating seed pieces in the field experiments described above, it was noted that few wireworms were present and practically no injury had re-

Table 5.—Toxicity of benzene hexachloride to wireworms in potted cauliflower plants, New Brunswick, N. J 1946

Pounds per Acre	No. Alive	No. Dead	Condition of Plants
3 Γ-benzene hexachloride	0	31	Growing normally. Roots and stems free of damage
5 Γ-benzene hexachloride	0	30	Growing normally. Roots and stems free of damage
10 Γ-benzene hexachloride	0	24	Growing normally. Roots and stems free of damage
Check	33	2	Roots and stems damaged, plants dead or wilted

sulted. This raised the question, is benzene hexachloride toxic or is it a repellent to wireworms? In order to determine this point a controlled laboratory experiment was conducted.

Eight-inch flower pots were filled with top soil and calculated amounts of benzene hexachloride dust diluted with an inert carrier were mixed thoroughly with the soil in each pot. Quantities of the 1 per cent dust were applied to the soil in the pots to give dosages per acre of 3, 5 and 10 pounds of the gamma isomer, and the treatments were triplicated with an untreated check for each replication. Cauliflower plants were set in these pots on April 17, 1946, and wireworms secured from the field were introduced into the pots as follows. Wireworms were introduced into each pot on May 13, and on May 31, 1946. The cauliflower plants were allowed to grow until June 6, when the soil was screened from each pot and mortality counts were taken. The following table gives the results of the experiment.

Effect on Quality of Potatoes.—Reports of men who took home potatoes from the field and ate them were that there was an unpleasant taste and odor present. Samples of potatoes from the various treatments were boiled in the laboratory and tasted by 23 persons. Although 5 of the tasters had no preference, more than 50 per cent rated one or more of the treated samples as tasting better than untreated checks.

Samples of potatoes from treated and untreated plots were also submitted to the Home Economics Department of the New Jersey Agricultural Extension Service for quality tests. The potatoes were boiled and baked and the three tasters all rated one or more of the treated samples better than samples from the untreated checks. The above tests indicated that most people could not detect any impairment of flavor due to the benzene hexachloride treatments.

Conclusions.—1. Results of tests with benzene hexachloride in New Jersey to date for wireworm control in potato fields indicate that it is outstanding. This is shown by the results of both field and laboratory experiments during 1945 and 1946.

2. Results indicate that good control was obtained with dosages of benzene hexachloride as low as 1.6 pounds of the gamma isomer per acre applied as a fall treatment, and 2 pounds of the gamma isomer per acre applied in the spring before the potatoes were planted.

3. DDT applied at 25 pounds of the technical grade material per acre in one test was promising for wireworm control.

4. No plant injury was noted from any of the treatments, except for a slight retardation of germination from the 10 pounds per acre dosage of benzene hexachloride.

5. Since these tests were of a preliminary nature, further work remains to be done to determine the proper dosage, method of application, effect of treatment on quality of potatoes, etc.—11-21-46

Dichloro-diphenyl-dichloroethane Compared With Other Materials for Corn Earworm Control[1, 4]

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During 1945 it was noted when harvesting the second generation European corn borer dust plots that DDD gave a marked reduction in corn earworm, *Heliothis armigera* (Hbn.), and fall army-worm, *Laphygma frugiperda* (A. & S.), populations in comparison to the other treatments. Therefore DDT, along with other insecticides was tested for corn earworm control on both early and late sweet corn in New Jersey during the 1946 season. The insecticides were applied by three different methods, namely with a bellows-type knapsack duster, with power dusters and by airplane.

Lead arsenate was used merely as a standard of comparison in the experiments, although we knew that arsenical injury on sweet corn under New Jersey conditions is usually rather severe. Also, there is the problem of lead and arsenical residue on corn at harvest, which even though arsenical injury did not occur makes this insecticide undesirable for use on sweet corn. However, no burning was observed with the use of lead arsenate in our experimental plots this season.

MATERIALS.—Five insecticides were selected for use in the corn earworm control studies at Landisville, New Jersey, on early sweet corn. The dichloro-diphenyl-dichloroethane,[3] used was prepared by diluting the 50 per cent factory mixed material to the desired 3 per cent concentration with talc. The method of preparation of the DDT and di(p-methoxyphenyl) trichloroethane was the same as for DDD using the 50 per cent factory prepared dust and diluting it to the 3 per cent concentration with talc. The lead arsenate was diluted to contain 20 parts of lead arsenate to 80 parts hydrated lime. The *Toxaphene*[5] contained 50 per cent of the crude material in the original mixture and it was prepared to contain 3 per cent 3956 in the final mixture, talc being used as the diluent.

The two most promising insecticides on early sweet corn, DDD and DDT, were used in the practical applications on late sweet corn at Milltown, New Jersey. The DDD was prepared to contain 3 per cent in the final mixture as outlined above, talc being the diluent. The DDT was mixed with talc at a concentration of 5 per cent. All the above dusts were mechanically mixed with a *Messinger* dust mixer.

EARLY SWEET CORN: *Procedure.*—Sweet corn at three stages of growth in three adjacent fields was selected for use in this experiment. In field 1 the dusts were applied after pollination was complete and the silks were dead, and about 10 days before harvest. Pollination had just taken place when the materials were applied to the silks and tassels in field 2. The tassels of the sweet corn in field 3 were dusted before the corn had produced silks.

The plots in each of the three fields were duplicated and were four rows wide and approximately 30 feet long. The experimental dusts were applied by hand with a bellows-type *American Beauty* knapsack duster on the three experiments. On another field, application of 3 per cent DDD dust was made with a four row tractor drawn power duster. An airplane was used to apply 3 per cent DDD to another field of sweet corn approximately the same age. With the hand and power dusters, the materials were applied so as to give a dust deposit on the silks and tassels of the plants. The application of DDD dust by airplane spread evenly over the field, therefore, only relatively small amounts of the insecticide was deposited on the tassels and silks. The insecticides were applied July 3, 1946, and infestation records made July 8, 1946.

Counts of the corn earworm larvae present were made by examination of 50 ears in each treatment in fields 2 and 3. In field 1, 25 ears were examined per treatment. The tip of the ear was clipped off with a knife and a thorough examination made for live larvae.

[1] Insecticides used in these tests were furnished by Rohm and Haas Company, Hercules Powder Company, the Sherwin-Williams Company, and E. I. du Pont de Nemours and Company, Inc.

[2] Journal Series paper of the New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.

[3] DDD or *Rhothane.*

[4] Eastern Branch Program.

[5] Herclues Powder Co.

Table 1.—Results of corn earworm studies on early sweet corn, 25 ears examined in each treatment. Sweet corn dusted after silks were pollinated and dead, Landisville, N. J. 1946

TREATMENT	TOTAL EARWORMS 5 DAYS AFTER DUSTING	PER CENT CONTROL
Dichloro-diphenyl-dichloroethane 3%	4	83.3
Dichloro-diphenyl-trichloroethane 3%	5	79.2
Toxaphene 3%	8	66.7
Lead arsenate 20%	8	66.7
Di(p-methoxyphenyl) trichloroethane 3%	13	45.8
Check	24	—

RESULTS.—The infestation of corn earworm was rather high in all the plots before treatment. Of the insecticides tested in this experiment, 3 per cent DDD was the most promising. Tables 1, 2 and 3 give the results obtained with the materials tested in these experiments.

Table 2.—Results of corn earworm studies on early sweet corn, 50 ears examined in each treatment. Sweet corn dusted at time of pollination, Landisville, N. J. 1946.

TREATMENT	TOTAL EARWORMS 3 DAYS AFTER DUSTING	PER CENT CONTROL
Dichloro-diphenyl-dichloroethane 3%	3	92.3
Dichloro-diphenyl-trichloroethane 3%	11	71.8
Toxaphene	17	56.4
Lead arsenate 20%	18	53.8
Di(p-methoxyphenyl) trichloroethane 3%	21	46.2
Check	39	

Table 3.—Results of corn earworm studies on early sweet corn, 50 ears examined in each treatment. Sweet corn dusted before silks were produced, Landisville, N. J. 1946.

TREATMENT	TOTAL EARWORMS 14 DAYS AFTER DUSTING	PER CENT CONTROL
Dichloro-diphenyl-dichloroethane 3%	6	82.4
Dichloro-diphenyl-trichloroethane 3%	9	73.5
Toxaphene 3%	11	67.6
Di(p-methoxyphenyl) trichloroethane 3%	13	61.8
Lead arsenate 20%	20	41.2
Check	34	—

LATE SWEET CORN: *Procedure.*—In view of the promising results obtained with DDD against the corn earworm in the tests on early sweet corn, large scale field tests of this insecticide on late sweet corn were conducted. The dusts were applied with a two row power duster, the materials being directed onto the ears and silks. The tips of the ears were slit with a knife and examined for live earworm larvae in the silks and the ear tips. A total of 100 ears was examined in each treatment and the check.

RESULTS.—The results of this experiment showed that DDD gave fairly good control of the corn earworm, while DDT rated second best. Table 4 shows the results obtained in this experiment.

Table 4.—Results of practical applications of DDD and DDT for control of corn earworm on sweet corn, Milltown, N. J. 1946.

TREATMENT	EARS EXAMINED	EARS INFESTED	PER CENT CONTROL
Dichloro-diphenyl-dichloroethane 3%	100	25	65.3
Check for DDD plot	100	72	—
Dichloro-diphenyl-trichloroethane 5%	100	33	40.0
Check for DDT plot	100	55	—

SUMMARY AND CONCLUSIONS.—Experiments were conducted in 1946 for the control of the corn earworm on sweet corn in New Jersey by the use of DDD and other materials when applied by knapsack duster, power duster and airplane.

Good control of the corn earworm was secured, with DDD rating superior to all other treatments in all tests.

The control of the corn earworm by airplane application of DDD was not as effective as the hand or power duster application of this material due to several factors such as distribution of dust, direction of flight, and width of swath.—11-21-46

Azobenzene Dusts to Control Red Spiders on Some Greenhouse Plants[1, 2]

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The use of azobenzene as a control for red spiders on roses has had a phenomenal development since Blauvelt (1945) showed that the material could be vaporized on hot steam pipes. Haring (1945), has reviewed the literature and given some data on the use of azobenzene as an acaricide and insecticide. He states that excellent control of red spiders in carnation houses was obtained by using a dust consisting of 20 per cent azobenzene and 80 per cent whiting.

The use of azobenzene as a fumigant is limited to those greenhouses that have steam heat. Here the azobenzene powder is mixed with water and painted on cold steam pipes; the steam is then turned on, and the azobenzene is driven off as a yellowish orange vapor. It may also be used in the form of candles or in pressure fumigators which burn and drive off the azobenzene. When used as a fumigant, it must be maintained at a fairly uniform concentration for about 6 hours, and it is not possible to fumigate just a part of a house. On the other hand, when azobenzene is applied as a dust it volatilizes slowly and if the dust can be placed on the lower surface of the leaves where the red spiders are located or if applied in fairly dense foliage which holds the fumes, a kill approaching that of the fumigation method is obtained. Azobenzene dusts have been used successfully in greenhouses which did not have steam heating, in houses which were not tight enough for fumigation, and on outdoor plants. It can also be used as a spot treatment, applications being made only to those plants showing red spider infestation.

The dust material used in most of the tests reported in this paper consisted of a micronized powder containing 70 per cent azobenzene and 30 per cent *Celite 209*. It was manufactured for use on the steam pipes and did not have very good dusting qualities. In some tests this 70 per cent azobenzene powder was diluted with *Pyrax ABB* and *Magnesite SFS No. 2264* so that the finished dusts contained 50, 40, 35, and 25 per cent actual azobenzene. These dusts had very good dusting properties.

In small tests the azobenzene dusts were applied with a hand duster. Most of the dusts, however, were applied with an electric power duster manufactured and sold for use in mushroom houses for control of flies. This duster had plenty of power but did not have a positive feed for the dust. Consequently it was sometimes rather difficult to apply the azobenzene dust uniformly.

Some preliminary tests with azobenzene dusts were made in the summer and fall of 1942 to determine their efficiency in the control of red spiders on roses. Because of other duties imposed by the war this work was discontinued early in 1943. These first tests were made with a dust *Azene* containing 20 per cent azobenzene and 80 per cent inert material.[3] In laboratory tests this dust gave a kill of 90 per cent or better of the two-spotted spider mite, *Tetranychus bimaculatus* Harvey. It did not adhere to the foliage and microscopic examination showed the azobenzene particles were considerably larger than the particles of the diluent. A technical grade of azobenzene was then dissolved in acetone, impregnated on *Loomkil* fibrous talc to give 20 per cent azobenzene, dried and ground in a ball mill. Samples of the *Azene* were also ground in the ball mill. The azobenzene particles were much smaller than before grinding and both materials adhered much better to the foliage. Tests with these materials gave a kill of the two-spotted spider mite varying between 70 and 88 per cent for all stages.

Work with azobenzene dusts was resumed in the early spring of 1946, when tests were made in a commercial rose greenhouse. The *Azene* dust containing 20 per cent azobenzene was compared with a dust containing 70 per cent azobenzene. The 20 per cent dust was applied at a somewhat heavier rate than the 70 per cent dust. A high kill of eggs and young was obtained with both dusts. The kill of mature spider mites ranged from 60 to 70

[1] Journal Series Paper of the New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.
[2] Eastern Branch Program.

[3] Obtained from Sherwin-Williams Co.

per cent. A second application made a week after the first treatment reduced the infestation further and when the house was fumigated with azobenzene about two weeks later the kill on the dusted areas was much better than elsewhere.

On June 7 approximately 300 young grafted magnolia plants, varying from 12 to 30 inches tall, in 6-inch pots, heavily infested with the two-spotted spider mite were dusted with the 70 per cent azobenzene dust. An examination made on June 14 of 25 large heavily infested leaves showed a kill of 89, 95, and 93 per cent respectively for the eggs, young, and adults. These and some additional magnolia plants were dusted on June 14. An examination made on June 24, 10 days after the second dusting, showed a kill of 81, 92, and 100 per cent respectively for the eggs, young, and adults of those plants receiving only the one dusting. The plants that had had two dustings showed a kill of 99, 99.3 and 98 per cent respectively for the eggs, young, and adults. A third application of the 70 per cent azobenzene dust was made on July 14. This treatment included some plants that had not previously been dusted. An examination made on July 25 showed a kill of 98, 84, and 83 per cent respectively for the eggs, young and adults on those plants receiving only the one treatment. Plants that had been treated on June 7, June 14, and July 14 showed a kill of 99.3, 99.2 and 99.1 per cent respectively of the eggs, young, and adults. A total of about 1500 plants were treated. No injury occurred to the plants except in a few instances where the dust was applied very heavily. The injury appeared as a burn and was not of commercial importance.

Late in July parts of two houses of chrysanthemums heavily infested with the two-spotted spider mite were dusted with 70 per cent azobenzene dust. The dust was applied with the electric power duster in one house, and with a small rotary fan type duster in the other house. Five days after treatment a control of 82, 99, and 100 per cent respectively of the eggs, young, and adults was obtained in the house dusted with the electric duster as compared with controls of 72, 78, and 73 per cent respectively for the house treated with the hand duster. The ventilators were closed during the dusting and the temperature was between 95 and 100° F. No injury to any of the chrysanthemums occurred, and the control of the red spiders was excellent.

About 600 Queen of the Pink chrysanthemums in 6-inch pots heavily infested with the broad mite, *Hemitarsonemus latus* (Banks), were dusted with a 50 per cent azobenzene dust on October 8. Examinations made on October 17 showed an average kill of 95 per cent of young and adults. Later examinations showed no increase in the infestation. It may be presumed, therefore, that the eggs were also killed. No injury occurred to the plants. Some of the chrysanthemum plants had considerable inert material left on the foliage after the azobenzene volatilized. They were sprayed with a 1 per cent nursery *Volck* solution which either washed off the inert dust or covered it up, since very little residue could be noted after the spraying.

Several commercial plantings of chrysanthemums have been dusted with the 70 per cent azobenzene dust with excellent control of the red spiders. The only known case of injury was in the Floricultural Department greenhouses where, of a number of varieties dusted, Golden Pierson and Gladys Pierson were badly burned.

On the 19th of July two large houses of hydrangeas at one of the commercial growers were treated with 70 per cent azobenzene dust for control of the two-spotted spider mite. The plants were in 6-inch pots and were from 10 to 18 inches tall. The temperature was about 92° F. before the ventilators were closed and in one house rose to 112° F. before the dusting was completed. The ventilators in one house were open shortly after the dust settled and were kept closed in the other house for 90 minutes after the dusting. Examinations made 4 days after the dusting showed essentially 100 per cent kill of the eggs and young and better than 75 per cent kill of the adults. All the hydrangea plants raised by this grower were treated with azobenzene dust before being set out in the field. No injury occurred to any of the plants and they remained remarkably free of red spiders throughout the summer and until brought into the greenhouse early in October. Early in November they were given another application of the 70 per cent azobenzene dust.

Carnations at the Florticultural Department's greenhouses as well as at several commercial growers have been dusted with 70 per cent azobenzene dust. Good control of red spiders has occurred with only a slight bleaching of the red colored varieties.

On July 8 and again on July 17, the 70 per cent azobenzene dust was applied with a small Hudson Admiral hand duster to a number of phlox plants growing outside in a garden. An examination made July 25 showed on undusted plants 500 dead and 2215 live red spiders as compared with 17 dead and 2 live ones on a similar number of leaves from the dusted plants. Several heavy rains following the dusting were probably responsible for washing off the dead red spiders on the dusted plants.

Two species of red spiders have been abundant on azaleas this fall in north Jersey. Plants of many varieties brought in from the field in early October were found to have the foliage severely injured, and after planting there was a heavy dropping of the leaves. One species of red spider concerned is the southern red mite, *Paratetranychus ilicis* (McG.). The other species is a flat reddish mite with oval bright red eggs and has been identified as *Brevipalpus* sp. This species was more abundant than the southern red mite. Plants were treated with dusts containing 50, 35, and 25 per cent azobenzene, applied with the electric power duster. The control of the southern red mite was excellent with all dusts. The control of the *Brevipalpus* species of red mite was also excellent where the dust had been well applied. On some of the raised benches it appeared that the excessive air blast from the electric blower blew the dust too hard and a good deposit was not obtained. In one house with raised benches where the dust was applied from the top of the plants, rather than from the side, excellent control was obtained with a dust containing 25 per cent azobenzene. On the ground benches very good kill was obtained with a 50 per cent azobenzene dust which was well mixed with inert material to give it good dusting properties. Some of the 50 per cent dust was not so well mixed, did not come out of the duster satisfactorily, and did not give a good control.

Azobenzene dusts have been used on a number of greenhouse plants to determine their tolerance to this material. Two plants which have shown rapid and severe injury when dusted with azobenzene dusts are the common violet and the African violet or Saintpaulia.

SUMMARY AND CONCLUSIONS.—1. Azobenzene dusts have a definite place in the control of several species of spider mites and the broad mite, particularly in houses where fumigation is not practical or where only a portion of the plants in a house need treatment. Dusts would also appear to be practical for spot treatments in rose greenhouses when it is not desirable to fumigate the entire house.

2. It would appear that dusts containing as little as 25 per cent of azobenzene, when thoroughly applied, will give a good control of most spider mites. It is probable however, that when the quantity of azobenzene applied by the duster can be well controlled a dust containing at least 50 per cent or more of azobenzene is to be preferred because of the smaller quantity of inert residue left after dusting.

3. There appears to be considerably less danger of injury to plants dusted with azobenzene than to plants fumigated with it. The dust can apparently be used at higher temperatures than can the azobenzene applied as a fumigant.

4. The azobenzene dust is effective in controlling three species of spider mites and the broad mite.

LITERATURE CITED

Blauvelt, W. E. 1945. Azobenzene for red spider on roses. New York State Flower Growers Bul. 2.
Haring, Robert C. 1946. Azobenzene as an acaracide and insecticide. JOUR. ECON. ENT. 39: 78–80.

Chemical Structure and Insecticidal Efficiency[1, 2, 3]

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For many years research workers have been attempting to correlate the structure of chemical compounds with their biological activity. Within limited fields these efforts have been successful, as demonstrated by the development of the barbiturate family of hypnotics, the sulfonamides, the cationic germicides, and the thiocyanate insecticides.

Apparently because of the complexity of the problem, no correlation studies of this kind have embraced any large number of different types of chemical compounds. The limited amount of biological test data in many fields precludes such broad studies in most cases, since it is hardly possible to draw general conclusions from a few compounds. Indeed, only in rare instances are enough data available to warrant such a broad study.

One of the few types of biological activity which has been intensively studied on a large, diverse, group of chemicals is the property of toxicity toward insect species. During years past many investigators, working in institutions and industrial laboratories, have made insecticidal tests on many thousands of compounds. A number of these tests have been reported in scientific journals and in domestic and foreign patent disclosures. From these reported data it should be possible to deduce whether or not there exists any generally applicable relationship between toxicity to insects and chemical structure. Such is the purpose of the present study.

Method.—The first phase of this investigation was the compilation of a list of tested chemicals. This was accomplished by a thorough search through all available literature, including patents relating to pest control. To the several thousand tested compounds obtained in this way was added an additional group contributed by research workers in response to the request published in one of the widely circulated scientific journals (Frear 1943). The final list included 6155 different chemicals, on most of which one or more insecticidal tests had been made. The only compounds included on which no test data were available were those listed in certain nonspecific patents.

The second part of the investigation involved the classification of the component portions of the chemical compounds included in the compilation. For this purpose an original procedure was developed, which has been published elsewhere (Frear *et al.* 1946). Briefly, in this classification procedure, a code number is assigned to each commonly-occurring chemical group. These code numbers (346 of which have been employed) in combination describe all of the compounds included in this compilation. In the 6155 compounds under study there were 23,554 individual groups, or an average of slightly less than four groups per compound.

The third step in this study consisted of the listing of the results of all insecticidal tests. Tests were recorded as positive if at least 10 per cent net toxicity was reported. The positive and negative tests were totaled for each compound tested, and these totals were assigned, for the purposes of this analysis, to each group in the compound. For example, on phenol one negative and four positive tests were reported. The benzene ring and the hydroxyl group were each credited with four positive and one negative test.

The final step was the correlation of the data obtained in the manner outlined in the previous paragraphs. For example, of the 6155 compounds, 451 contained the carboxyl (—COOH) group. On these compounds, a total of 518 insecticidal tests were recorded, of which 390 were positive and 128 were negative. The percentage of toxicity associated with the group was therefore 390/518 or 75.5.

Results.—Data on some of the 346 chemical groups encountered in this study are not presented in this paper since many groups occurred in only a small number of compounds. In the tables to follow only those groups represented by 10 or more tests are listed. In table 1 are given the results on organic groups, in table 2 the inorganic cations, in table 3 the inorganic anions, and in table 4 the organo-metallic groups. In all of these

[1] A mass correlation study of single chemical groups occurring in 6155 compounds from the literature.

[2] Eastern Branch Program.

[3] Authorized for publication on April 23, 1947 as paper No. 1371 in the journal series of the Pennsylvania Agricultural Experiment Station.

[4] General Aniline and Film Corporation Research Fellow.

Table 1.—Number and percentage of positive insecticidal tests recorded on compounds containing organic chemical groupings.

NAME		No. COMPOUNDS	No. TESTS	PER CENT POSITIVE
C_3 ring		24	24	100.0
C_2S ring		17	17	100.0
Dinitrile	$(-CN)_2$	6	13	100.0
C_5+C_6 fused ring system		13	13	100.0
C_{13} chain		8	11	100.0
Monothiocyanate	(-SCN)	347	369	98.4
Iodoxy	$(-IO_2)$	6	24	95.8
Pentachloro	$(-Cl)_5$	55	66	95.5
Monoisothiocyanate	(-NCS)	36	55	94.5
C_{11} chain		22	18	94.4
Multiple thiocyanate	$(-SCN)>_1$	65	47	93.6
Diether	$(-O-)_2$	397	410	93.2
Tetraphenyl		70	74	93.2
Iodoso	(-IO)	6	29	93.1
Multiple C_3 chains		97	100	93.0
Monoether	(-O-)	975	1037	92.9
$C>_{20}$ chain		26	28	92.9
Tetraether	$(-O-)_4$	16	14	92.9
Multiple chloro	$(-Cl)>_6$	15	14	92.9
C_4+C_6 fused ring system		11	13	92.3
C_{12} chain		93	85	91.8
$3-C_2$ chains		63	85	91.8
Tetrachloro	$(-Cl)_4$	118	134	91.0
$2-C_2$ chains		312	332	90.4
C_5O ring		65	101	90.1
Tribromo	$(-Br)_3$	23	30	90.0
Multiple C_4 chains		104	115	89.6
C_5+C_6 fused ring system		20	28	89.3
Cyclohexenyl		31	37	89.2
Trichloro	$(-Cl)_3$	113	129	89.1
Phenate, alcoholate	(-OM)	38	27	88.9
C_9 chain		14	18	88.9
Mono C_8 chain		121	130	88.5
Amide	(-CON=)	67	84	88.1
Dichloro	$(-Cl)_2$	269	314	87.6
Monocyclohexyl		274	299	87.6
Monochloro	(-Cl)	499	597	87.3
Trihydroxy	$(-OH)_3$	24	31	87.1
C_{10} chain		35	46	87.0
C_{18} chain		129	155	85.2
Mono C_7 chain		46	51	84.3
Triphenyl		285	318	84.0
Mono C_4 chain		452	534	83.9
Dibromo	$(-Br)_2$	79	98	83.7
Tetra C_1 chain		82	97	83.5
C_6+C_6 fused ring system		322	310	83.2
Monohydroxy	(-OH)	1126	1253	82.8
Mono C_2 chain		1033	1291	82.6
Azoxy	[-N:N(:O)-]	6	11	81.8
Hetero CO ring, >6 members		6	11	81.8
Monobromo	(-Br)	220	294	81.6
C_2O ring		26	32	81.3
C_4OS ring		23	31	80.6
Mono C_3 chain		553	625	80.3
Monoiodo	(-I)	82	106	80.2
Thioamide	$(-CSNH_2)$	15	30	80.0
Dicyclohexyl		31	30	80.0
Tetrabromo	$(-Br)_4$	13	25	80.0
Haloformic acid	(XCOOH)	11	15	80.0
Hydrazone	$(:NNH_2)$	9	10	80.0
Tri C_1 chain		238	278	79.1
Hetero CN ring, >6 members		22	43	79.1
Sulfonamide	$(-SO_2NH_2)$	128	167	79.0
Monothiol	(-SH)	43	76	78.9
Mono C_1 chain		1691	2164	78.0
Multiple phenyl, >4		15	18	77.8
Monocarboxylic ester		401	730	77.4

NAME		No. COMPOUNDS	No. TESTS	PER CENT POSITIVE
Acyl chloride	(–COCl)	17	17	76.5
Mono C_8 chain		230	266	76.3
Monophenyl		1904	2467	76.1
Tetra C_2 chain		23	25	76.0
Dihydroxy	$(–OH)_2$	221	219	75.8
Diphenyl		989	1217	75.5
Monocarboxylic acid	(–COOH)	451	518	75.5
Sulfonate	$(–SO_3H)$	338	327	75.2
C_4N ring		134	158	74.7
Monoamine (sec.)	(–NH–)	158	197	74.6
C_5N ring		281	322	74.2
Thiourea	(H_2NCSNH_2)	60	85	74.1
Dicarboxylic ester		103	92	73.9
C_4O ring		113	140	73.6
Triethers	$(–O–)_3$	25	26	73.1
Multiple C_6 chain		43	51	72.5
Triketone	$(–CO–)_3$	25	29	72.4
Mononitro	$(–NO_2)$	310	565	72.0
Quaternary ammonium		44	50	72.0
Hydrazine	(H_2NNH_2)	25	39	71.8
Di C_1 chain		609	668	71.7
C_{14} chain		11	14	71.4
Monoketone	(–CO–)	287	372	71.2
C_4ON ring		22	24	70.8
Dithiocarbamate	(H_2NCSSH)	31	44	70.5
C_3NS ring		76	60	70.0
C_4NS ring		37	50	70.0
Nitrosoamine	(H_2NNO)	8	20	70.0
Thiuram sulfide	$(H_2NCS–)_2S$	5	10	70.0
C_6 ring fused to heterocycles		381	542	69.1
Imines	(:NH)	18	22	68.2
C_5 ring		21	25	68.0
Mononitrile	(–CN)	45	56	67.9
Oxime	(:NOH)	20	27	66.7
Nitroso	(–NO)	12	24	66.7
Hexachloro	$(–Cl)_6$	11	18	66.7
Thioether	(–S–)	98	104	66.3
Monoamine (tert.)	(–N=)	89	109	66.1
Disulfide	(–S–S–)	25	38	65.8
Dinitro	$(–NO_2)_2$	152	221	65.2
Semicarbazide	$(H_2NNHCONH_2)$	4	17	64.7
C_5S ring		9	14	64.3
Monoamine (primary)	$(–NH_2)$	246	362	64.1
Amide	(–CONH–)	226	322	64.0
Dicarboxylic acid	$(–COOH)_2$	67	72	63.9
Sulfonyl chloride	$(–SO_2Cl)$	13	19	63.7
C_4N_2 ring		40	63	63.5
Guanidine	$[H_2NC(:NH)NH_2]$	37	65	63.1
Mono C_6 chain		87	97	62.9
Monofluoro	(–F)	29	24	62.5
C_4S ring		9	16	62.5
Thioketone	(–CS–)	14	21	61.9
Trinitro	$(–NO_2)_3$	29	26	61.5
Monoaldehyde	(–CHO)	64	112	60.7
Multiple C_1 chain, >4		41	47	59.6
C_3O_2 ring		20	27	59.3
C_{18} chain		26	26	57.7
$C_6+C_6+C_6$ fused ring system		31	44	56.8
Sulfone	$(–SO_2–)$	15	16	56.3
Azo	(–N:N–)	130	192	55.7
Amide	$(–CONH_2)$	21	36	55.6
Diketone	$(–CO–)_2$	89	123	54.5
C_4S_2 ring		9	11	54.5
Diiodo	$(–I)_2$	10	13	53.8
Semicarbazone	$(:NNHCONH_2)$	34	86	51.2
Sulfenyl chloride	(–SCl)	4	10	50.0

NAME		No. COMPOUNDS	No. TESTS	PER CENT POSITIVE
Diamine (sec.)	$(-NH-)_2$	10	10	50.0
Triiodo	$(-I)_3$	2	10	50.0
Diamine (primary)	$(-NH_2)_2$	43	61	49.2
$C_6+C_6+C_6$ fused ring system		36	51	47.1
Diamine (tert.)	$(-N=)_2$	14	17	47.1
Urea	(H_2NCONH_2)	15	21	42.9
Thiuram disulfide	$(H_2NCSS-)_2$	8	15	40.0
Multiple hydroxy	$(-OH)>_3$	11	10	40.0
C_2S_3 ring		5	10	30.0
C_3N_2 ring		24	36	19.4

tables the number of compounds in which the respective groups occur, the total number of insecticide tests on those compounds, and the percentage of these which were positive are shown.

Studies on combinations of more than one group in a compound will be presented in a subsequent paper.

DISCUSSION.—From table 1 it may be seen that several organic groups are associated with an apparent toxicity of 100 per cent. These are the C_3 ring, the C_2S ring, dinitriles, C_5+C_6 fused ring systems (an example of which is indan), and the C_{13} chain. Since these groups are represented by a limited number of tests, their location in the table is perhaps fortuitous. Among those groups represented by a greater number of tests, mention should be made of the high apparent toxicity associated with the thiocyanates (single and multiple), the polychloro groups (Cl_5,

Table 2.—Number and percentage of positive insecticidal tests recorded on compounds containing inorganic cationic groups.

NAME	No. COMPOUNDS	No. TESTS	PER CENT POSITIVE
Selenium	12	12	100.0
Zirconium	11	11	100.0
Titanium	12	10	100.0
Arsenic	9	20	90.0
Cerium	13	14	85.7
Chromium	10	19	84.2
Zinc	37	41	80.5
Lanthanum	12	15	80.0
Thallium	12	15	80.0
Iron	7	10	80.0
Sodium	161	220	78.6
Mercury	23	14	78.6
Ammonium	71	82	76.8
Potassium	82	106	76.4
Aluminum	13	23	73.9
Calcium	27	52	67.3
Lead	32	53	66.0
Copper	78	102	65.7
Cadmium	13	17	58.8
Magnesium	16	29	58.6
Antimony	16	16	56.3
Barium	46	67	50.7
Cobalt	8	10	10.0

Table 3.—Number and percentage of positive insecticidal tests recorded on compounds containing inorganic anionic groups.

NAME		No. COMPOUNDS	No. TESTS	PER CENT POSITIVE
Fluosilicate	$=SiF_6$	31	57	100.0
Fluoborate	$-BF_4$	12	11	100.0
Orthoarsenite	$\equiv AsO_3$	17	27	96.3
Metaarsenite	$-AsO_2$	12	12	91.7
Orthoarsenate	$\equiv AsO_4$	15	51	91.0
Thiocyanate	$-SCN$	18	37	86.5
Hydroxide	$-OH$	52	61	83.6
Fluoride	$-F$	63	86	79.1
Oxide	$=O$	50	84	76.2
Iodide	$-I$	25	24	75.0
Sulfate	$=SO_4$	83	141	73.8
Chloride	$-Cl$	143	156	72.4
Cyanide	$-CN$	19	38	71.1
Borate	$\equiv BO_3$	14	20	70.0
Sulfide	$=S$	22	36	69.4
Bromide	$-Br$	29	28	64.3
Nitrate	$-NO_3$	18	31	54.9
Orthophosphate	$\equiv PO_4$	44	31	51.6
Carbonate	$=CO_3$	25	41	46.3

Table 4.—Number and percentage of positive insecticidal tests recorded on compounds containing organo-metallic chemical groupings.

NAME	No. COMPOUNDS	No. TESTS	PER CENT POSITIVE
Lead	14	49	100.0
Tin	8	12	100.0
Phosphorus	82	83	96.4
Antimony	18	18	95.0
Arsenic	26	30	76.7

Cl_4, Cl_3, and Cl_2) and the ethers.

Among those groups associated with the lowest toxicity, many are represented by small numbers of tests. However, many nitrogen-containing groups (azo, unsubstituted amide, semicarbazone, diamines, urea, and C_3N_2 heterocyclic rings) appear in compounds of low toxicity.

Several interesting series in table 1 show the effect on insecticidal activity of multiplication of like groups in a molecule. A few of these series are presented in table 5. It is apparent from this table that compounds containing increasing numbers of chlorine atoms have increasing apparent toxicities, compounds having one chlorine atom being associated with 87.3 per cent toxicity, those with three chlorine atoms, 89.1 per cent toxicity, and those with five chlorine atoms showing 95.5 per cent toxicity. The fact that there is a regular trend toward increasing toxicity with increasing chlorine content is probably of some significance, although the chi-square test showed no significant differences between successive members of the series. This relationship between high toxicity and multiple chlorine atoms is of particular interest because of the known toxicity of DDT and hexachlorocyclohexane, both of which contain high percentages of chlorine.

Similar trends are observable with 1, 2 and 3 bromine atoms, although the presence of 4 bromine atoms appears to result in lower toxicity. A definite reversal occurs, on the other hand, with an increase in numbers of iodine atoms.

The relative toxicities of halogen-containing compounds may also be seen in this table. It appears that the toxicities associated with compounds containing one chlorine, bromine or iodine atom are about the same (80.2 to 87.3 per cent), while that associated with compounds containing a single fluorine atom is considerably less.

Compounds containing two amine groups are in general less toxic than those with one such group. This is true for primary, secondary, and tertiary amines. Compounds containing ether linkages or nitro groups likewise show decreased effectiveness with increase in number of like groups.

The multiplication of some groups appears to result in increased toxicity up to a certain point, beyond which a reverse effect is produced. This is apparent in the bromine series mentioned above, and in the C_2 chain series. In both of these cases the peak of toxicity occurs when three like groups are present in the molecule.

Table 5.—Percentages of positive insecticidal tests recorded on compounds containing various numbers of like organic chemical groups.

Group	Number of Like Groups in Compound				
	1	2	3	4	5
Chlorine	87.3	87.6	89.1	91.0	95.5
Bromine	81.6	83.7	90.0	80.0	
Iodine	80.2	53.8	50.0		
Fluorine	62.5				
Amine (primary)	64.1	49.2			
Amine (sec.)	74.6	50.0			
Amine (tert.)	66.1	47.1			
C_2 chain	82.6	90.4	91.8	76.0	
Ether	92.9	93.2	73.1		
Nitro	72.0	65.2	61.5		

These series represent only a few of the possible combinations; an examination of data presented will reveal many other relationships which may be of interest to research workers.

Table 2, which shows the percentages of toxicity associated with inorganic cations, presents some apparent anomalies. The relative positions of certain of the cations in this table are not in accord with the common conceptions of their toxicity. For example, while arsenic and chromium might be expected to, and do, occupy high positions in the table, one would not expect sodium, ammonium, and potassium to precede lead, copper and antimony. A possible explanation of these results may be found in the fact that many sodium, ammonium, and potassium salts of toxic organic and inorganic compounds are represented in the present series. Further testing of larger numbers of compounds containing these groups may change their order considerably.

On the other hand, the data on inorganic anions in table 3 are more closely in line with established facts. Those groups which are generally agreed to have toxic properties, fluosilicate, fluoborate, arsenite, arsenate, thiocyanate and fluoride, occupy the highest positions in the table. The groups which are of known low toxicity, such as nitrate, phosphate and carbonate, are found low in the table.

Table 4 includes groups in which inorganic elements are attached directly to carbon, and which may be loosely termed organo-metallic groups. Although the data are hardly sufficient to warrant any broad conclusions, it is significant that the toxicities associated with all of these groups are relatively high.

The authors are aware that several sources of error are inherent in the procedure used in this paper to establish the correlations. Of these, probably the most important is the tendency of research workers to report only positive tests in the literature. In a series of tests, it is quite natural for the workers to discard early those compounds showing low toxicity, and to record in the final report only those materials showing the greatest promise. This tendency is more obvious in the older literature than in more recent publications. A further selection has been made in most reported tests because of the fact that the types of compounds chosen for tests are usually selected as the result of previous indications of toxicity. The effects of these selections of data are observable in table 1, in which all but four of the groups listed are associated with a relative toxicity greater than 40 per cent. Of the 346 groupings studied, 308 were associated with toxicities greater than 50 per cent.

In this study each insecticidal test was given equal value. This has introduced another source of error, since it is obvious that variations in experimental technique, including such important factors as concentration, method of application, and test organism used are capable of producing widely divergent results, even on the same compound. The practical difficulties involved in a critical examination of the large mass of data involved here made any attempt at such appraisal impractical.

It is also recognized that an error is introduced by the assignation of the toxicity found for a whole compound to each of its parts.

In spite of the errors inherent in this study, the authors feel that the findings are significant because of the relatively large number of compounds and tests included. The findings are offered as a guide for workers who are interested in the synthesis of insecticidal materials. With the information developed, it should be possible to judge in advance the likelihood that compounds containing specific chemical groups will be insecticidally effective.

SUMMARY.—A total of 6155 chemical compounds on which insecticidal tests have been made has been collected from published and unpublished results. The constituent chemical groupings present in these compounds have been studied in relation to the results of the toxicity tests. It has been found that certain of these groups are regularly associated with high toxicity, while others are associated with low toxicity. The findings are presented as a guide for workers who are interested in the synthesis of compounds of insecticidal value.—11-21-46.

LITERATURE CITED

Frear, D. E. H. 1943. A catalogue of insecticides and fungicides. Science **98**: 535.

Frear, D. E. H., E. J. Seiferle and H. L. King. 1946. A new classification system for chemical compounds. Science **104**: 177–8.

SCIENTIFIC NOTES

Notes on the Mosquitoes of Louisiana[1]

WILLIS W. WIRTH

This paper is a partial report of a study begun in 1941 as a survey of the mosquitoes of East Baton Rouge Parish in Louisiana. In 1942 and 1943 the writer was stationed as an entomologist in the Malaria Control in War Areas program of the United States Public Health Service at Alexandria, Louisiana, with supervision of entomological inspectors at military and defense installations in Caddo Bossier, Webster, Lincoln, Ouachita, Rapides, Vernon, Beauregard, Calcasieu, and Lafayette Parishes. In addition to numerous mosquito surveys made in these areas, the writer identified approximately 13,000 mosquitoes from New Jersey light traps (Table 1). A total of 49 species of mosquitoes are known to occur in Louisiana, of which forty-four have been taken or examined by the writer. The seasonal occurrence of these species in Louisiana is shown in table 2.

NOTES ON RARE OR UNUSUAL SPECIES.—1. *Anopheles walkeri* Theobald. Rare in Louisiana, breeding in freshwater marshes with abundant vegetation; numerous adults and larvae were taken from marshes at Contraband Bayou near Lake Charles in May and June 1943.

2. *Anopheles crucians georgianus* King. Biological notes for Louisiana records of this variety have been given previously (1944) by the writer. The larvae occur typically in acid side-hill seepage puddles characteristic of cut-over longleaf pine lands.

3. *Anopheles pseudopunctipennis* Theobald. A single female of this southwestern species was taken in a light trap at Lake Charles on October 22, 1942.

4. *Taeniorhynchus perturbans* (Walker). This species was taken while biting at Conrad's Point near Baton Rouge in June, 1941, and was quite troublesome in areas around Camp Claiborne near Alex-

[1] Contribution No. 88 from the Department of Zoology, Physiology and Entomology, Louisiana State University, Baton Rouge, Louisiana. Acknowledgment is gratefully extended to Dr. O. W. Rosewall and Dr. J. H. Roberts of Louisiana State University and to Mr. E. B. Johnson of the Louisiana State Board of Health for valuable assistance and guidance in this study. The work was aided by a financial grant from the Louisiana Academy of Sciences in 1941.

Table 1.—Light trap collections by Louisiana parishes, from malaria control in war areas reports, July 1942 to April 1943.

	BOSSIER		OUACHITA		VERNON		RAPIDES		CALCASIEU	
	3[1]	100[2]	4	72	2	136	10	668	1	60
Aëdes aegypti	—		1		—		34		1	
sollicitans	1		—		—		8		16	
taeniorhynchus	—		—		—		1		3	
vexans	142		110		52		173		121	
spp.	1		—		3		1		—	
Anopheles crucians	20		22		13		73		3428	
pseudopunctipennis	—		—		—		—		1	
punctipennis	8		19		10		31		1	
quadrimaculatus	70		101		23		441		438	
walkeri	—		—		—		—		25	
Culex apicalis	1		15		—		13		—	
quinquefasciatus	10		9		405		372		—	
restuans	—		6		32		20		3	
salinarius	40		23		82		119		—	
tarsalis	8		5		—		8		2	
Culex (Culex) spp.	170		406		354		2100		1546	
Culex (Melanoconion) spp.	4		15		13		109		514	
Culiseta inornata	885		446		155		300		464	
Orthopodomyia signifera	1		—		—		3		—	
Psorophora ciliata	1		—		1		12		6	
Psorophora confinnis	771		6		57		1291		486	
discolor	92		—		5		107		25	
ferox	2		—		2		4		—	
spp.	—		—		3		4		—	
Taeniorhynchus perturbans	—		1		1		—		124	
Uranotaenia lowii	6		20		888		746		—	
sapphirina	44		15		37		124		—	
spp.	—		—		—		268		5703	
Totals	2275		1220		2136		6362		12906	

[1] Number of traps.
[2] Number of trap-nights.

andria (June–July, 1942) and at Contraband Bayou near Lake Charles (April–May, 1943). Following the taxonomic discussions of Edwards (1941) and Barreto and Coutinho (1944) it is concluded that the generic name *Taeniorhynchus* Lynch-Arribalzaga should replace *Mansonia* Blanchard.

5. *Psorophora horrida* (Dyar & Knab). Roth (1945) has recently shown that in the United States more than one species have been confused under the name *P. horrida*. True *P. horrida* occurs in the Eastern States east of western Louisiana, Arkansas and Missouri, while old records from west of this area pertain to a species Roth described as *P. longipalpis*. Roth checked Baton Rouge specimens of *horrida*, and the writer has in addition definite records from West Carroll Parish, May 15, 1945 (Wirth); Beauregard Parish, October 13, 1942 (Buren); and Rapides Parish, June 26, 1943 (Buren).

Table 2.—Seasonal collections of mosquitoes in Louisiana, 1941–1947.

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
Aëdes aegypti				x			x	x	x	x	x	
atlanticus				x	x	x	x	x	x			
canadensis		x	x	x	x	x	x					
dupreei			x	x	x	x	x	x				
fulvus pallens				x	x	x	x					
Aëdes grossbecki	x	x		x	x							
infirmatus			x	x	x	x	x	x				
mitchellae				x								
sollicitans			x	x	x	x	x	x	x	x	x	x
sticticus				x	x							
Aëdes taeniorhynchus			x	x	x	x	x	x	x	x		
thibaulti				x								
tormentor			x	x	x	x	x	x				
triseriatus	x	x	x	x	x	x	x	x				
vexans	x	x	x	x	x	x	x	x	x	x	x	
Anopheles barberi			x	x	x	x	x	x	x	x		
crucians	x	x	x	x	x	x	x	x	x	x	x	x
pseudopunctipennis										x		
punctipennis	x	x	x	x	x	x	x	x	x	x	x	
quadrimaculatus	x		x	x	x	x	x	x	x	x	x	x
Anopheles walkeri				x	x	x		x	x	x	x	
Culex apicalis	x	x	x	x	x	x	x	x	x	x	x	x
erraticus				x	x	x	x	x	x	x	x	x
peccator							x	x				
quinquefasciatus	x	x	x	x	x	x	x	x	x	x	x	x
Culex restuans	x	x	x	x		x		x		x	x	x
salinarius				x	x	x	x		x	x	x	x
tarsalis									x	x	x	x
Culiseta inornata	x	x	x	x					x	x	x	x
melanura		x	x			x		x				x
Megarhinus septentrionalis		x	x			x	x	x	x	x		
Orthopodomyia signifera	x	x	x	x	x	x	x	x	x	x	x	
Psorophora ciliata				x		x	x	x	x	x		
confinnis				x	x	x	x	x	x	x	x	
cyanescens				x	x	x						
Psorophora discolor					x	x	x	x	x	x		
ferox			x	x	x	x	x	x	x	x	x	
horrida				x	x	x	x	x				
howardii				x		x	x	x	x			
longipalpis				x								
Psorophora varipes				x	x	x	x					
Taeniorhynchus perturbans				x	x	x	x	x	x	x		
Uranotaenia lowii							x	x	x	x	x	
sapphirina				x	x		x	x	x	x	x	

6. *Psorophora longipalpis* Roth. The writer reared a collection of this species including a male with the peculiarly enlarged genitalia from Rapides near Alexandria, April 1, 1943. No previous records of *P. longipalpis* from Louisiana are known.

7. *Aëdes grossbecki* Dyar & Knab. This is a rare generally single brooded early spring species, breeding in semipermanent woodland pools in sloughs in which the water will remain for several weeks when flooded. As very little has been written concerning the biology of *A. grossbecki*, the following notes are presented.

Near Alexandria on January 25, 1943, large *Aëdes grossbecki* larvae were taken in a shallow woodland pool in an old slough in association with *Culex restuans*. This pool dried up and when flooded by rains a month later larvae of *A. grossbecki* were again taken on February 26, this time with *Culex restuans*, *Aëdes canadensis*, *Aëdes vexans*, and *Culiseta inornata*. When this pool was visited again on March 31, after having been flooded a third time, *A. grossbecki* larvae were not found, only *Aëdes canadensis*, *Aëdes tormentor*, and *Psorophora ferox* larvae. Another location approximately five miles from the above was visited on April 1, 1943, and large *A. grossbecki* larvae and pupae were found in woodland pools in association with *Culiseta inornata* and *Anopheles punctipennis*. Hundreds of adults were captured at this time from their resting places on the trunks of nearby trees, generally less than a foot from the ground or water surface. They were not found more than fifty feet from their breeding pools and did not attempt to bite (1 to 4 P. M. on a sunny day), but toward evening they became more restless and hard to catch. The *A. grossbecki* adults were particularly well camouflaged for their habit of resting on tree bark, the mesonotal markings harmonizing perfectly.

Females of *Aëdes grossbecki* were taken biting very warily during the day in woods near Bayou Macon, West Carroll Parish on May 15, 1944, following heavy spring rains which had flooded the low swampy woods. Larvae of *A. grossbecki* were taken in association with *A. vexans* from a semipermanent woodland pool in a slough at this same location on February 17, 1947, following heavy rains.

8. *Culex peccator* Dyar & Knab. The writer (1945) has given keys to distinguish males and larvae of this species from the other United States species of the subgenus *Melanoconion*. As *peccator* is an uncommon species not much has appeared concerning its biology. Generally the larvae are said to occur in stream pools and marshy areas, nearly always associated with *Culex apicalis*. At Baton Rouge the writer made two collections of *C. peccator* in August, 1941. The first was in a semipermanent woodland pool in a deep swamp which when newly flooded had bred the woodland *Aëdes* and *Psorophora* quite heavily; at the time of collection of *C. peccator* somewhat later, it was the only species present. The second collection was in water collected in the base below ground level of a large hollow tupelo gum tree in a swamp. The tree cavity was open only by a narrow crack extending up about six feet on one side leaving the interior very dark. The *C. peccator* larvae were associated with larvae of *Culiseta melanura*. This particular tree was one of a number with hollow bases which had been under surveillance as possible breeding places of *Aëdes thibaulti*.

9. Species not taken by the writer, but known to occur in Louisiana. *Anopheles atropos* Dyar & Knab is common in the coastal salt marshes (King *et al.*, 1944). *Orthopodomyia alba* Baker, a rare tree hole breeding species closely allied to *O. signifera*, was reported by Harden (1946) from New Orleans. *Culex nigripalpus* Theobald and *C. pilosus* (Dyar and Knab) have been reported by King *et al.* (l.c.) from New Orleans.—5-15-47.

Literature Cited

Barreto, M. P., and Coutinho, J. O. 1944. Sobre o genero *Taeniorhynchus* Arr. 1891 com a descricao de tres novas especies do subgenero *Taeniorhynchus* (Diptera, Culicidae). Arq. de Hyg. e Saude Publica, **60:** 51–86.

Edwards, F. W. 1941. Mosquitoes of the Ethiopian Region III. Culicine adults and pupae. London.

Harden, P. A. 1945. The occurrence of *Orthopodomyia alba* Baker at New Orleans, Louisiana. Mosquito News, **5:** 131.

King, W. V., Bradley, G. H., and McNeel, T. E. 1944. The mosquitoes of the Southeastern States. U. S. Dept. Agr. Misc. Pub. No. 336.

Roth, L. M. 1945. The male and larva of *Psorophora* (*Janthinosoma*) *horrida* (Dyar & Knab) and a new species of *Psorophora* from the United States (Diptera: Culicidae). Proc. Ent. Soc. Wash., **47:** 1–23.

Wirth, W. W. 1944. Notes on the occurrence of *Anopheles georgianus* King in Louisiana. Jour. Econ. Ent., **37:** 446.

Wirth, W. W. 1945. The occurrence of *Culex* (*Melanoconion*) *elevator* Dyar and Knab in Florida, with keys to the Melanoconions of the United States (Diptera, Culicidae). Proc. Ent. Soc. Wash., **47:** 199–210.

Increasing Production of Codling Moth Eggs in an Oviposition Chamber

E. R. Van Leeuwen, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The following is a report of an attempt to increase the number of eggs laid by the codling moth, *Carpocapsa pomonella* (L.), in an oviposition chamber held at 80° F. The study reported here was preliminary to an extensive investigation of the olfactory response of newly hatched codling moth larvae, for which large numbers of eggs were required.

The two oviposition chambers used in this study were located in a constant-temperature room in the basement of the laboratory. The doors of these chambers faced an outside window and were made of wire screen. A cylindrical wire cage, 12 inches long and 4 inches in diameter, was used for holding the material tested. The liquids were absorbed on a piece of towling 30 inches long by 15 inches wide, rolled to fit inside the wire-cylinder cage.

One thickness of waxed paper was wrapped around the cage, which was then placed on the floor of the chamber near the door. Under this arrangement, moths did not come in contact with the materials tested. The test material was alternated daily, except during week-ends, between the two chambers, and an equal number of observations were made in each chamber. In table 1 are given the materials used

Table 1.—Comparative effect of different materials on codling moth oviposition in cages.

Materials Compared		Period of Test	Eggs Deposited in—		Increase Over Check
Test	Check		Test cage	Check cage	
		Days	*Number*	*Number*	*Per Cent*
Water	No water	6	1,192	743	60
Old apples[1]	Water	16	1,908	215	787
Old apples+water	Water	10	4,672	1,742	168
Molasses bait (10%)	Water	12	6,858	2,570	167
Old apples	Fresh apples[1]	10	5,860	3,320	77

[1] "Old apples" were those many days out of winter storage, and "fresh apples" were those used soon after removal from storage. All apples used were of the Rome Beauty variety.

and the number of eggs deposited on the wax paper surrounding the cylindrical cage.

During the period in which the tests were made, 54 observations were recorded. At every observation except two a larger number of eggs was deposited on the paper surrounding the test materials than on that surrounding the check material. The results indicate that codling moths can be stimulated to produce a larger number of eggs when moisture, apples, or molasses bait are added to the oviposition chamber.

While using apples in the chamber for increased egg production, there was a marked decrease in numbers of eggs following a change from old, partly decayed apples to apples fresh from winter storage. To determine the time required for fresh apples to increase egg production, a test was made comparing the attractiveness of fresh apples with that of water. The same apples were used throughout the experiement and the water and apples were alternated each day between the two chambers, as in the previous tests. For the first 6 days of the test 4,383 eggs were deposited with water present and 2,180 eggs with apples added. During the remaining 4 days of the test period the egg production was greater with apples present in the chambers. The number of eggs deposited was 4,857, as compared with 2,950, or an increase of 65 per cent in favor of the use of apples.—5-23-47.

Effect of 2,4-D on Sugarcane Borer

J. W. INGRAM, E. K. BYNUM, and L. J. CHARPENTIER,[1] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The herbicide 2,4-dichlorophenoxyacetic acid, known as 2,4-D, is now used by many growers in sugarcane fields to control weeds. To determine the effect of this chemical on the first generation of the sugarcane borer, *Diatraea saccharalis* (F.), in 1946 the writers examined the young canes injured by this generation, or so-called dead hearts, in weed-control plots under study by George Arceneaux of the U. S. Bureau of Plant Industry, Soils, and Agricultural Engineering. In one experiment eight twentieth-acre plots and five fortieth-acre plots were treated with three applications of 2,4-D spray about three weeks apart, each at the rate of 1 pound of 70 per cent 2,4-D per acre, and three 0.05 plots and seven 0.025-acre plots were not sprayed but were hoed as necessary to control the weeds. The infestation averaged 35 borers per acre in the sprayed plots and only 8 borers per acre in the hoed plots.

These findings indicated the need of additional studies on the effect of 2,4-D on the sugarcane borer. A random-block experiment of six 6-row, 0.05-acre plots per treatment was therefore conducted on summer-planted cane during September and October 1946. Seven treatments were compared in this experiment, all of which were applied as dusts at the rate of approximately 8 pounds of the dust mixture per acre. Where 2,4-D was used, it was applied at the rate of 1 pound of 2,4-D per acre. In one treatment two applications of 2,4-D mixed with pyrophyllite only were made two weeks apart. In the other treatments four weekly applications were made a week apart. In one treatment the 2,4-D was mixed with synthetic cryolite (90 per cent sodium fluoaluminate) for the second and fourth applications, the other two applications being synthetic cryolite alone; and in another treatment it was mixed with a pyrophyllite dust containing 50 per cent of sodium fluosilicate for the second and fourth applications, the other two applications being 50 per cent sodium fluosilicate alone. The first application of all treatments was made on the same day.

Since it was already known that over 95 per cent of all surviving borers cause dead hearts in cane plants of the size treated in this experiment, the effect of the various treatments on the borer population was determined by examining all dead hearts in the center four rows of each plot with the exception of 3 feet at each end. Results of this examination are given in table 1. In the plots receiving two applications of 2,4-D only, the borer population was 44 per cent greater than in the untreated check plots. In the plots where 2,4-D was added to synthetic cryolite in two of the four applications the borer population was 38 per cent greater than in the plots receiving cryolite alone, and where it was added to 50 per cent sodium fluosilicate in two of the four applications the number of borers was 85 per cent greater than in the plots receiving sodium fluosilicate alone.

Table 1.—Effect of 2,4-D, alone or combined with synthetic cryolite or sodium fluosilicate in pyrophyllite, on the sugarcane borer population in summer-planted cane. Houma, La., 1946.

Treatments	Live Borers per Plot
Cryolite only	9.8
Sodium fluosilicate only	5.3
Sodium fluosilicate plus 2,4-D alternated with sodium fluosilicate only	9.8
Cryolite plus 2,4-D alternated with cryolite only	13.5
2,4-D only	50.8
Check, no treatment	35.3
Differences required for significance at odds of 19:1	11.3
99:1	15.2

In an effort to determine the reason for the heavier infestations in plots receiving 2,4-D, the four middle rows in the plots that received two applications of 2,4-D only, and in the untreated plots,

[1] W. E. Haley collaborated in the project.

were examined to determine the numbers of borer eggs present and the degrees of parasitization by *Trichogramma minutum* Riley. Unhatched eggs that showed no evidence of parasitism were held for a week to determine whether they had been parasitized. This examination was not made until 3 weeks after the last 2,4-D application, but there had been no rain since that application and 2,4-D was still visible on the sugarcane plants. The average number of eggs per plot was 281 in the treated plots and 230 in the untreated plots, and the average percentage of parasitization was 49 in the treated plots and 60 in the untreated plots. Thus there were 22 per cent more eggs and 18 per cent less parasitization on the treated plots than in the untreated plots. These data indicate that the heavier infestation in the treated plots may have been largely due to the detrimental effect of the 2,4-D treatment on parasitism by *T. minutum*.

It is apparent that, under prevailing conditions, 2,4-D caused a material increase in the sugarcane borer infestation. Although these results from one season's work are by no means conclusive, they do indicate the desirability of further studies on the possible effect of 2,4-D on the abundance of the sugarcane borer and other insects.—5-14-47.

Use of Potato Tubers in Mass Culture of Diaspine Scale Insects[1]

STANLEY E. FLANDERS, *University of California Citrus Experiment Station, Riverside*

The Division of Biological Control of the University of California Agricultural Experiment Station has developed a comparatively inexpensive method of mass-culturing various diaspine scale insects. The propagation of these insects has been in preparation for testing the effectiveness of their natural enemies in the field when such enemies are released periodically in inundative numbers—that is, in numbers sufficient to search effectively the plant surfaces likely to be inhabited by the scale host at a time when the host population is low.

At intervals during the past ten years various types of plant hosts have been tested in the laboratory for the red scale, *Aonidiella aurantii*, the San Jose scale, *Aspidiotus perniciosus*, and the latania scale *A. lataniae* (LePage 1942; Flanders 1936, 1943, 1944). The hosts tested have included date palm seedlings, iris plants, fronds of *Cycas revoluta*, and fruits of *Citrus*, *Citrullus*, and *Cucurbita*. None of these was entirely satisfactory from the standpoint of efficient and economic mass culture of diaspine scale insects. Recently, the potato tuber has been found to be suitable as food for a number of species, and a satisfactory medium for their mass culture.

Space is utilized most efficiently when egg-sized potato tubers are used. These are packed closely together to form a single layer on trays made of 0.5-inch hardware cloth supported by a wooden frame. Infesting of the potatoes and parasitization of the scale occur after the potatoes are trayed. The tubers are held on the trays until discarded.

Mass infesting of potato tubers with scale insects that are not positively phototropic to a high degree,

[1] Paper No. 568, University of California Citrus Experiment Station, Riverside, California.

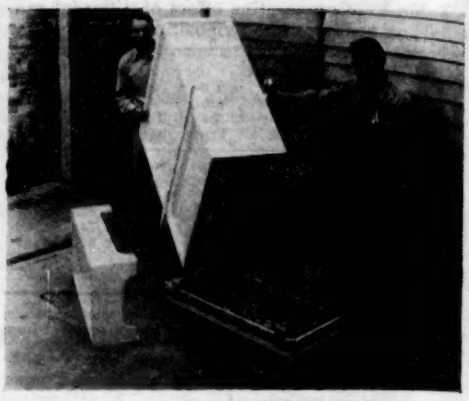

FIG. 1.—Trays of potatoes in position to receive scale crawlers, after being covered by housing (left) and flue-like settling chamber (center).

such as red scale, is accomplished by placing uninfested potatoes below "mother" potatoes already heavily infested with scales that are producing young. The young scales either drop naturally or are blown off artificially at intervals. Artificial infestation is the more efficient method, since the uninfested tuber then receives a maximum infestation in a minimum of time and few scales are lost by dispersion. If the "mother" tuber is heavily infested, so that the population of mature scales fully occupies its surface, the settling of the newly hatched young is retarded and a greater percentage of them may thus be blown off.

The potatoes are artificially infested by setting the filled trays under a flue-like settling chamber (Fig. 1). The number of trays under the chamber needs to be sufficient to catch all the crawlers drifting through them. A tray of infested "mother" tu-

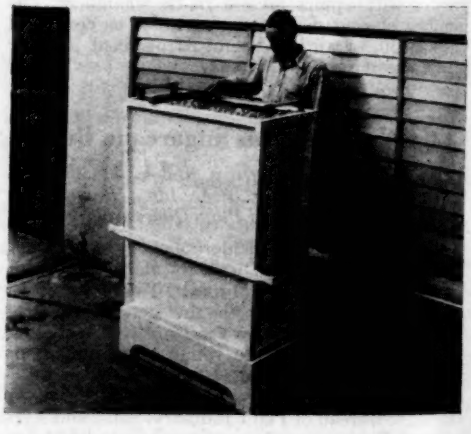

FIG. 2.—Settling chamber with "mother" tray set in the top in position for blowing scale crawlers into chamber. The air issues through minute holes one-half inch apart along metal tube attached to air hose. The wooden slat attached to tube, opposite the row of air holes, serves to limit the sweeping action of air blast as the tube is moved over the "mother" tray.

bers bearing newly hatched crawling scale is set in the top of the settling chamber (Fig. 2), where it is exposed to a blast of air sufficiently strong to dislodge the crawlers. When blown into the chamber, the crawlers settle on the potatoes in the trays beneath. If these trays are encased so that the air does not pass out laterally, very few crawlers fail to become lodged on the potatoes. "Mother" trays are "blown" at the rate of one per minute. To obtain a high degree of infestation with such species as red scale, which tend to establish themselves at the point of fall, the upper and the lower surfaces of the potatoes are exposed beneath the settling chamber on successive days.

With latania scale (a thelyotokous species) three "mother" trays will yield enough young to infest a fresh tray daily for several months. Newly infested trays should be held for a time in a dark room.

With species that are positively phototropic, such as latania scale, the newly hatched crawlers can be forced by proper lighting to leave the "mother" potato tubers and converge at a point where they may be readily collected. Artificial infesting is then accomplished by "dusting" the crawlers onto the tubers in the trays. The method of infesting potato sprouts with newly hatched crawlers of black scale (*Saissetia oleae*) collected phototropically was reported earlier (Flanders 1942).

The "drop" method of infesting potato tubers is less laborious than either the "blowing" or the "dusting" method, since the infesting is automatic, the young scale produced by an upper stack of "mother" trays dropping naturally to a lower stack of fresh trays. This method can be used efficiently with both red and latania scales, provided enough heavily infested "mother" trays are used in the upper stack to permit the infesting of a fresh lower-stack tray within a 4-day period. A sufficient number of fresh trays (six or more) should be stacked beneath the "mother" trays to catch all the newly hatched scale that drop. When the tray at the top of this stack is completely infested, it is removed and a fresh tray is placed at the bottom of the stack. The accumulation of scale on the tubers in the lower-stack trays should be sufficient to infest one side. Then as each tray reaches the top of the stack, just under the bottom tray of the "mother" stack, the potatoes are turned so that the opposite side is exposed to infestation.

The egg-sized, mature, non-mealy potato tuber appears to be the most suitable plant host for the mass culture of diaspine scales. The reasons for this may be summarized as follows:

(1) Its use eliminates the necessity for providing facilities for propagation of the host plant, since an adequate supply of the tubers can be purchased at low cost in the open market throughout most of the year. The cost per unit of plant surface habitable by the scale is thus less than for other known types of host plants.

(2) The potato tuber can be held in cold storage if necessary.

(3) It can be handled with a minimum amount of labor.

(4) It can be housed in such a way as to provide the maximum scale-supporting area per unit of space.

(5) Without loss of viability, the potato tuber can support for over 30 days mature scales covering 100 per cent of its surface. Since the mature red scale produces young over a period of a month or more, its efficient use requires that it inhabit a host plant which remains viable during this period. Some tubers may carry heavy infestations of scale for six months at 80° F.

(6) Loss of scale due to decomposition of food plant is less with the potato than with the melon or squash.

(7) The potato tuber can be readily infested with minimum wastage of scale, a flat type of tuber, such as that of the White Rose, being especially suitable for this purpose.

(8) It can be completely infested with scales of equal age. Its use thus permits a rapid turnover of material, and, consequently, a maximum production of host and natural enemy in the minimum of time and space.

(9) It permits the handling of scale infestations in compact units that can be efficiently utilized in the culture of natural enemies.

(10) Its use facilitates the liberation of immature natural enemies.—6-15-47.

LITERATURE CITED

Flanders, S. E. 1936. *Coccidophilus citricola* Brèthes, a predator enemy of red and purple scales. JOUR. ECON. ENT. 29(5): 1023–4.

Flanders, S. E. 1942. Propagation of black scale on potato sprouts. JOUR. ECON. ENT. 35(5): 687–9.

Flanders, S. E. 1943. Mass production of the California red scale, and its parasite *Comperiella bifasciata*. JOUR. ECON. ENT. 36(2): 233–5.

Flanders, S. E. 1944. Observations on *Prospaltella perniciosi* and its mass production. JOUR. ECON. ENT. 37(1) 105.

Lepage, H. W. 1942. Aboboras, cobaias para o estude das pragas dos vegetais. O Biologico VIII(9): 221–4.

Fluorine Residue on Cucurbits[1]

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In connection with investigations on the pickleworm, *Diaphania nitidalis*, a number of determinations of fluorine residue were made on crops dusted with cryolite and barium fluosilicate, in order to know what residue may be expected when dusting for pickleworm is necessary. It is generally assumed at present that fluorine residues under 7 milligrams per kilogram of fresh fruit are not dangerous for human consumption. This is the present tolerance established by the U. S. Food and Drug Administration on apples and pears.

PROCEDURE.—Fruit was brought in from the field, cut into short lengths, placed in screw-top fruit jars, and frozen. This material was thawed and thoroughly disintegrated in a Waring blendor. The mass of blended material was then placed in the bowl of an electric mixer and aliquot portions were removed for moisture and fluorine analyses while the material was being rapidly mixed.

[1] Contribution from the Departments of Chemistry, Horticulture, and Entomology, North Carolina Agricultural Experiment Station.
Published with the approval of the director as Paper No. 261 of the Journal series.
[2] Professor of entomology.
[3] Assistant professor of chemistry.
[4] Research professor of horticulture.

The blended sample was prepared for distillation following the method of Crutchfield (1942), using magnesium acetate as the ashing agent. Evaporation to dryness was accomplished by an infra-red lamp instead of an electric burner. The ashed sample was mixed with silver sulfate, as described by McClure (1939), to prevent vaporization of chlorides, and transferred to a Claisen flask by means of a spatula and a brush, the last portion being loosened from the inside of the nickel crucible with a toothbrush. About 240 ml. of distillate was collected in a 250-ml. volumetric flask during the steam distillation with perchloric acid following MacIntire & Hammond's (1939) variation of the procedure of Willard & Winter (1933). The distillation apparatus used has been described previously.[1] The distillate was diluted to the mark in the 250-ml. volumetric flask. Usually 5 or 10 ml. of this solution, depending on its concentration, was used for the determination of fluorine according to the back-titration method of Dahle *et al.* (1938). Results were reported in terms of milligrams of fluorine per kilogram of fresh fruit.

The first determinations were made on straight neck summer squash which had been dusted with undiluted cryolite and barium fluosilicate. Two samples of each were taken, one immediately after dusting and the other five days later after one shower of .73 inch. The samples were of mixed large and small fruits of marketable quality. They were carefully handled to prevent excessive rubbing of the surface. Each sample was divided into two lots by splitting the fruits lengthwise. Otherwise they were treated the same as the cucumbers.

RESULTS.—Separate determinations were made on each lot of squash, with results as shown in table 1.

Table 1.—Fluorine residues on summer squash.

DUST USED (UNDILUTED)	TIME OF PICKING	MG. OF FLUORINE PER KG. (DUPLICATE SAMPLES)	
Cryolite	after dusting	9.50	9.71
Cryolite	5 days later	2.42	2.91
Barium fluosilicate	after dusting	10.68	12.13
Barium fluosilicate	5 days later	4.17	4.21

Further determinations were made on cucumbers for it is apparent that this crop presents a greater hazard when small pickle sizes are used, on account of the greater surface area per unit of weight. To determine the maximum amount that could be expected on cucumbers, some plants were dusted heavily with undiluted cryolite and barium fluosilicate and the crop was picked immediately after dusting. Determinations were made on three sizes of cucumbers, designated as follows:

Size 1, diameter 1.25 inches or less.
Size 2, diameter 1.25 to 1.75 inches.
Size 3, diameter over 1.75 inches.

The results of these analyses are shown in table 2.

Parts of three samples were washed in a rotary vegetable washer using water without a detergent. Determinations on the washed and unwashed parts were as follows:

Cryolite, size 2, unwashed 8.08, washed 1.60.
Cryolite, size 3, unwashed 6.80, washed 1.61 and 1.12.
Barium fluosilicate, size 3, unwashed 6.80, washed 2.54.

[1] In. Assn. Official Agr. Chem. 1940.

Table 2.—Fluorine residues on cucumbers picked immediately after a heavy dusting with undiluted dust.

DUST	CUCUMBER SIZE	NUMBER OF DETERMINATIONS	MG. OF FLUORINE PER KG.	
			Range	Average
Cryolite	1	7	8.3–11.70	10.5
Cryolite	2	1	8.05	8.05
Cryolite	3	1	3.12	3.12
Barium fluosilicate	1	6	9.19–17.80	13.62
Barium fluosilicate	3	2	6.80– 6.86	6.83

Cucumbers which received a light shower between dusting and picking had a much lower residue. One lot, which was picked three days after dusting with undiluted cryolite, had received a light shower recorded as .1 inch a half mile from the field. Residue determinations for the three sizes of cucumber in this lot were as follows: size 1, 6.53; size 2, 2.24 and 2.34; size 3, 1.69 mg. of fluorine per kg. A similar sample which was picked while wet during a very light shower and received no other rain also gave very low residue determinations. Sizes 1 and 2 mixed had 1.60 mg. and size 3 had .53 mg. of fluorine per kg.

In later fluorine determinations on cucumbers some very small sizes were used and all sizes were determined accurately by weighing and counting. Cryolite dust was applied in two dilutions, containing 33 per cent and 50 per cent of the active ingredient. The dust was applied at the usual rate for pickleworm control.

When computed, the amount of mixed dust per acre varied from 20 pounds on the smaller plants to 40 pounds on the larger plants, which covered practically the whole area between rows.

The crop was picked as usual before dusting and the samples were picked 2 or 3 days later. No rain fell on any sample during the interval. The results are summarized in table 3.

CONCLUSIONS.—The results shown in table 3 would indicate that small cucumbers numbering 30 or more per pound may be expected to have a fairly large fluorine residue when dusted with any cryolite mixture which would be effective for pickleworm control, if no rain falls on the plants between dusting and picking. Large cucumbers numbering less

Table 3.—Fluorine residues in relation to cucumber size.

FRUITS PER LB.	DUST PER CENT CRYOLITE	DETERMINATIONS	MG. OF FLUORINE PER KG.	
			Range	Average
4	33	4	3.45– 3.91	3.68
9	33	4	2.68– 4.07	3.41
29	33	4	7.00– 8.00	7.49
41	33	2	12.01–12.48	12.25
100	33	1		26.79
3	50	2	2.80– 2.90	2.85
6	50	2	3.97– 5.18	4.58
9	50	4	4.34– 5.37	4.82
29	50	4	7.88– 9.84	8.90
56	50	2	14.56–14.62	14.59

10 per pound probably will not retain a residue of more than 7 mg. even if not rained on.

Samples dusted with barium fluosilicate generally retained a larger fluorine residue than those dusted with cryolite. Results taken from samples which had been washed or rained on, indicate that both dusts are rather easily removed from cucumbers and squash and any simple washing process would probably reduce the residue below 7 mg. per kg. If summer squash crops are picked clean just before dusting it is doubtful if the next picking would have a very heavy residue even if no rain falls. Cucumbers for commercial pickles are either washed in a vegetable washer or cured in brine which is later removed by several changes of water. During the process the pickles may be handled several times while wet. No analyses were made on brined samples. However, the results on washed samples indicate that no large residue would be retained on brined pickles even in the small sizes.

LITERATURE CITED

Assoc. Official Agr. Chem. 1940. Official and Tentative Methods of Analysis, Chap. 6, p. 51.

Crutchfield, W. E., Jr. 1942. Ind. Eng. Chem., Anal. Ed., **14**: 58.

Dahle, D., R. U. Bonnar, and H. J. Wichmann. 1938. Jour. Assoc. Official Agr. Chem., **21**: 459.

McClure, F. J. 1939. Ind. Eng. Chem., Anal. Ed., **11**: 171.

MacIntyre, W. H., and J. W. Hammond. 1939. J. Assoc. Official Agr. Chem. **22**: 231.

Willard, H. H., and O. B. Winter. 1933. Ind. Eng. Chem., Anal. Ed. **5**: 7.

Chironomid Larvae in a Tobacco Seed Bed

A. I. BOURNE and F. R. SHAW

On April 10, 1947, the authors received a report of an infestation of a tobacco seed bed by fly larvae. They were reported as occurring in masses on the surface of the soil. It was suspected that the larvae might prove to be those of a species of Sciara. Reports have been made in the past, of the presence of such larvae in groups several feet long.

Upon investigation, it was found that the soil in the seed bed was literally swarming with tiny larvae. It was possible to secure several hundred by scooping up small samples of earth. The larvae were examined and were determined as a species of the family Chironomidae.

Records of the larvae of Chironomidae, as occurring in soil, were unknown to the authors. It was decided to attempt to rear the specimens in order to obtain specific determinations, Pupae were found within a few days after the larvae were brought into the laboratory and in about a week, adults began to appear.

Specimens of the adults were sent to Dr. O. A. Johannsen at Ithaca, N. Y. for determination. The following information is based on the report of Dr. Johannsen.

These flies were originally described as *Chironomus aterimus* Meigen. Later the species was placed in the genus *Camptocladius* and is so placed in the New York State List. The present classification is *Smittia aterrimus* (Meigen). Dr. Johannsen also adds that these larvae have been recorded as feeding upon the root hairs of various plants including tobacco seedlings.

In the present instance, no damage to the seedlings occurred since the insects had completed their development and the adults had emerged before the seedlings were up.

It is somewhat difficult to explain the presence of the larvae in the soil in the practically fully developed condition. A fertilizer, containing cotton seed meal, had been applied prior to the seeding of the beds, whether the insects would be attracted by this is a matter of conjecture. The seed beds were located near a strip of marshy lands, and it was thought possible that the insects had begun their development in this area and then had migrated to the seed beds.

A final examination on May 12 showed no signs of the insects in any stages in the seed beds. The tobacco seedlings seemed to be developing normally and the stand was fully as good as in adjoining tobacco seed beds in which no insects had been present.—5-23-47.

Toxicity of Gamma-Benzene Hexachloride to Preimaginal Stages of the Housefly[1]

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Although several practical insecticides and contrivances have been developed to control the adult housefly, *Musca domestica* L., none has yet proved generally satisfactory in practice to combat the immature stages. Larvicides in general, however, have shown the greatest promise and feasibility. Recent investigations by McGovran & Piquett (1945) indicate that gamma-benzene hexachloride (gamma-1,2,3,4,5,6-hexachlorocyclohexane) is superior in killing power to DDT, borax and thiourea for the third instar larvae. McDuffie *et al.* (1946) obtained high efficiency in field trials with this compound against blowflies in animal carcasses. The same authors observed a considerable degree of residual action from the use of the compound. About the same time, Bovingdon (Slade 1945), Gersdorff & McGovran (1945), Savit *et al.* (1946) and others found in laboratory tests a high order of toxicity for the gamma isomer to adult houseflies.

The results of a study of the toxicity of benzene hexachloride to eggs, to second and third instar larvae and to pupae of the housefly are reported in this paper.

MATERIALS AND PROCEDURE.—Preliminary tests to determine the range of toxicity were conducted with technical benzene hexachloride (10 to 12 per cent gamma isomer) and a proprietary water dispersible preparation formulated to contain 100 per cent of technical material. Final tests were made with a chemically pure sample of the gamma isomer (m. p. 112.5°C.).[2] Gum arabic-water dispersions based upon the per cent by weight of toxicant per total volume were employed.

Eggs, 1 to 4 hours old, second instar larvae 2 to 3 days old, third instar larvae 4 to 5 days old and pupae 1 to 2 days old were used in the experiments.

[1] Summary of Master's Thesis, Iowa State College. Acknowledgement is made of the assistance offered by Dr. C. H. Richardson who directed the investigation.

[2] Thanks are due the E. I. du Pont de Nemours and Company of Wilmington, Delaware for the chemicals used in these tests.

Table 1.—Comparative dosage-mortality relationships and statistics of the experimental egg, larval and pupal populations of the housefly, *Musca domestica* L.

Insect Stage and Method	Type of Benzene hexachloride Material Used	Mean Sub-sample Size	Range of Replicates	Number of Dosages	LD_{50} mg./l.	LD_{95} mg./l.	Slope	Control Mortality Per Cent
Egg: glass-covered	Gamma[1]	126	3–13	8	Nontoxic	Nontoxic	—	8.72
2nd instar larva: glass-covered	Gamma	33	6–14	6	3.2	13.5	2.644	2.08
3rd instar larva: cloth-covered	Technical[2]	35	2–10	12	86.0	528.6	2.085	3.96
3rd instar larva: glass-covered	Technical	31	2–9	12	121.4	599.0	2.373	3.03
3rd instar larva: glass-covered	Gamma	40	7–29	9	18.5	83.8	2.512	4.02
3rd instar larva: culture medium	Gamma	47	19–20		4.5	15.3	3.111	8.78
3rd instar larva: sawdust medium	Gamma	48	10	5	6.8	23.6	3.059	5.19
Pupa: glass-covered	Gamma	38	5–13	8	618.0	17,900.0	1.125	4.37

[1] Benzene hexachloride (1,2,3,4,5,6-hexachlorocyclohexane).
[2] One hundred per cent technical proprietary water-dispersible powder.

The insects were placed on or between two discs of paper toweling cut to fit 50 ml. stender dishes to which was added a measured quantity of the insecticidal preparation. No food was added at any time. Stender dish covers conserved moisture and permitted some ventilation as evidenced by the low mortalities in check containers.

Counts of normal, abnormal and dead ova were made at the end of 24 hours, and mortality of second instar larvae was recorded at the end of 48 hours; ability to crawl normally was established as the criterion of survival. For the third instar larvae, normal pupation and emergence of adults were taken as suitable survival criteria, and for pupae, emergence of normal adults.

Although the compound is known to possess contact, stomach poisoning and respiratory action (Martin & Wain 1944; Shaw 1945), differentiation of these properties lay outside the scope of this study. It is probable that this triple effect would function advantageously in the practical application of the material.

In other less extensive tests the toxic action of the compound was investigated by incorporation, as per cent by weight per volume, in an artificial culture medium consisting of whole, crimped oats, alfalfa meal, barley malt (brewer's), fresh yeast and tap water, and in a finely-milled softwood sawdust. These two media simulated more natural conditions and the latter proved to be a convenient, practically nontoxic substrate for testing the insecticide. The culture medium further served the dual purpose of a larval nutriment and adult oviposition substrate in rearing the experimental colonies. The frequently overlooked consideration of the effect of the breeding medium on the toxicity of insecticides could be studied to some extent in this way. The media were covered with muslin to permit more rapid escape of gases and so to minimize lethal respiratory action.

Dosage-mortality curves, LD_{50}'s, LD_{95}'s and other appropriate statistics were calculated according to the method of Bliss (1935). The most pertinent data are given in table 1.

Results.—Gamma-benzene hexachloride was practically nontoxic to ova even at a high dosage level (4.0 to 8.0 g. per 100 ml.). A rapid post-incubation poisoning effect, however, was exhibited. It is suggested that this factor would contribute appreciably to the overall mortality in suppressive measures.

Second instar larvae were the most susceptible. A dosage of 3.21 mg. per liter gave 50 per cent mortality. Nearly all young larvae were dead within 24 hours, the great majority perishing much before this. Some repellent action was observed both on larvae of this instar and on third instar larvae but a careful analysis of this point was not made. Loeffler & Hoskins (1946) report gamma-benzene hexachloride as strikingly toxic to third and fourth instar larvae of *Lucilia sericata* (Mg.), but to exhibit only moderate repellency.

The tests with third instar maggots gave relatively high mortality at extremely low dosages. An LD_{50} of 18.54 mg. per liter was calculated from a large number of samples. Somewhat lower LD_{50}'s of 4.52 and 6.86 mg. per liter were obtained for third instar larvae in synthetic culture and sawdust media respectively. It is possible that increased stomach poisoning and respiratory action in these media may account for these differences. Chemical interactions of the insecticide and the culture ingredients might also be responsible for some of the increased toxicity.

The pupal stage was considerably more resistant than the larval stages. An LD_{50} of 618.0 mg. per

liter indicates this fact. It is clearly possible, however, that even this stage might be controlled at practical field dosages.

SUMMARY.—A slightly modified technique for testing insecticides against immature stages of the housefly is briefly described. Sawdust is a useful medium for testing larvicides when a semi-solid substrate is desired. Gamma-benzene hexachloride is nontoxic to the egg, but is markedly toxic to second and third instar larvae and to pupae of the housefly. In the order of decreasing tolerance the stages are: ova—pupae—third instar—and second instar larvae. The results indicate a high degree of larvicidal efficiency in laboratory experiments and suggest that gamma-benzene hexachloride is a potentially practical field larvicide for this insect. Further work is necessary to properly appraise the field performance of the compound.—4-26-47.

LITERATURE CITED

Bliss, C. I. 1935. The calculation of the dosage-mortality curve. Ann. Appl. Biol. 22(1) 134–67.

Gersdorff, W. A., and E. R. McGovran. 1945. Insecticide toxicity studies. Experimental results on the comparative toxicity of benzene hexachloride, DDT, and pyrethrum extracts to houseflies. Soap and San. Chem. 21(11): 117, 121.

Loeffler, E. S., and W. M. Hoskins. 1946. Toxicity and repellency of certain organic compounds to larvae of *Lucilia sericata*. JOUR. ECON. ENT. 39(5): 589–97.

Martin, H., and R. L. Wain. 1944. The qualitative examination of insecticidal properties. Long Ashton Res. Sta. Ann. Rept. 1944: 121–40.

McDuffie, W. C., A. W. Lindquist, and A. H. Madden. 1946. Control of fly larvae in simulated pit latrines and in carcasses. JOUR. ECON. ENT. 39(6): 743–9.

McGovran, E. R., and P. G. Piquett. 1945. Toxicity of benzene hexachloride to housefly larvae. JOUR. ECON. ENT. 38(6): 719.

Savit, J., J. J. Kollros, and J. M. Tobias. 1946. Measured dose of gamma hexachlorocyclohexane (gamma 666) required to kill flies, and cockroaches, and a comparison with DDT. Proc. Soc. Exptl. Biol. Med. 62(1): 44–8.

Shaw, H. 1945. The new insecticides DDT and benzene hexachloride and their significance in agriculture. Jour. Royal Agric. Soc. England 106: 204–20.

Slade, R. E. 1945. The gamma isomer of hexachlorocyclohexane (Gammexane) an insecticide with outstanding properties. Chem. and Indust. 40(23): 314–9.

Clover Leaf Weevil Control with DDT Dust

HAROLD GUNDERSON, *Iowa State College, Ames*

Severe infestations of the clover leaf weevil, *Hypera punctata* (F.) appeared in red and sweet clover in Iowa during May, 1947. Farmers were alarmed by the damage and requested assistance in controlling the pest. Favorable reports of the effectiveness of DDT-oil sprays made by Potts *et al.* (1945) encouraged us to try airplane application of DDT dusts under Iowa conditions.

Field counts in red clover 50 per cent defoliated by clover leaf weevils showed average populations of 6 larvae of all stages per plant or 12 per square foot. In heavier stands of red clover, less apparent damage was seen although populations still averaged 10 to 12 larvae per square foot.

A light airplane equipped for dusting was used to apply 20 pounds of 5 per cent DDT in talc per acre on May 24. The swath covered on each trip was 30 feet wide. Seventeen acres were treated in 15 minutes. A 60-foot check strip was left untreated.

On May 26, it was almost impossible to find a live weevil larva in the treated area. In the untreated check, the population still ranged from 4 to 6 larvae of all stages per plant. The treated clover was recovering from the damage and a definite line of demarcation was visible between the treated and untreated portions of the field.

In a heavier stand of red clover nearby, treated in the same way on May 24, about 50 per cent of the larvae were killed. The difference in results may be explained by the relatively much denser growth in the second field, preventing the dust from coating all the leaves.—6-7-47.

LITERATURE CITED

Potts, S. F., T. E. Bronson, Randall Latta, and F. W. Poos. 1945. Atomized concentrated sprays containing DDT to control pea aphid and clover leaf weevil. JOUR. ECON. ENT. 38(4): 497.

The Lesser Grain Borer in Wheat in the Field

GEO. A. DEAN, *Kansas Agricultural Experiment Station, Manhattan*

The lesser grain borer, *Rhizopertha dominica*, Fab., which is one of the smallest beetles injurious to stored grain, is widely distributed in the United States, Southern Canada, Argentina, India, and Southeast Australia. It is known to many grain dealers as the Australian wheat weevil. In addition to wheat, it also attacks rice, wood, and the bindings and inner portions of books.

During the last few days of June, 1947, wheat kernels taken from wheat heads growing in the field in southwestern Kansas were sent to the Department of Entomology, Kansas State College, showing damage by the adults or beetles of the lesser grain beetle. The damaged wheat was examined also by Dr. R. T. Cotton, in charge of the Bureau of Entomology Research Laboratory, United States Department of Agriculture, Manhattan, Kansas. While we do not know of any published record of this insect infesting the grain growing in the field, we do know it is a strong flyer and there is no reason why it should not attack grain in the field. This is especially true when millions of bushels of wheat are grown and stored in elevators and bins in close proximity to the grain fields.

The lesser grain borer is a small, slender, cylindrical beetle, 0.19 inch long and 0.03 of an inch wide. It is dark brown or black, with a roughened surface. Its head is turned down under the thorax. The female lays from 300 to 500 eggs. The period from egg to adult in summer is about one month.—7-13-47.

Codling Moth and European Red Mite Control and Seasonal Analysis of Spray Deposits

CASTILLO GRAHAM AND ERNEST N. CORY,
University of Maryland, College Park

In the spring of 1946, 16 plots of 20 year old trees were selected for codling moth and European red mite experiments. The orchard from which the plots were selected had received excellent care for several years from the standpoint of pruning, spraying and fertilizing. The trees were planted 40 by 40 feet and each plot selected for the experiments consisted of six Stayman Winesap and three York Imperial trees. The sprays through the petal fall were applied by the grower and consisted of the regular arsenate of lead in the petal fall and a scab spray of 4 pounds of wettable sulfur to the 100 gallons between the petal fall and the first cover. The remainder of the sprays were applied by the writer using a spray machine with a 400-gallon tank and a 35 gallons per minute capacity pump. A minimum of 30 gallons of spray was applied per tree per application using 700 pound pressure. Each plot received from 1 to 3 applications of bordeaux for scab control in combination with the insecticidal sprays.

Records on codling moth injury were made on all of the drop apples through the season from each plot and from a sample taken from each field box at harvest time (Table 1).

The data on the number of European red mites was taken by making counts of the actual number of red mite and red mite eggs from a sample of 10 leaves from each plot on five different dates. The counts were made in the orchard at the time each sample of leaves was collected without the loss of any adult mite or mite eggs by handling. A total of 50 leaves from each plot was examined (Table 1).

The project on spray deposit on apple foliage at different periods during the spraying season was inaugurated at the request of the fruit growers. The growers felt that with a definite knowledge of the amount of deposit required to kill codling moth worms, and with suitable laboratory facilities to make quick analysis of foliage, timing of the various sprays could be more effective.

Samples of foliage from the top, center and bottom of the same tree in each plot were collected several times during the season. The first collections were made on May 25 and the last on August 15. The analyses were made of the grains of DDT or lead arsenate per pound of foliage and per square inch of leaf surface.

Table 1.—Number of worms in ground and tree run apples, average number of red mites per leaf, DDT and lead analyses of fruit collected on different dates during the season.

PLOT	COVER	DATE	SPRAY MATERIALS PER 100 GALLONS OF WATER	APPLES EXAMINED	WORMS	DDT GR./LB. COL. DIFFERENT DATES		AVERAGE NO. RED MITE PER LEAF
1	1st	5/22	2 lbs. benzene hexachloride, 8 oz. actual DDT, 1 pt. spreader[1]	Ground	704	No		36
				Tree run	2000	0	Analysis	
	2nd	6/4	The same as 1st cover					
	3rd	6/17	The same as 1st cover					
	4th	7/1	The same as 1st cover					
	5th	7/24	The same as 1st cover					
2	1st	5/22	2 qts. 30% DDT emulsion	Ground	808	2	7/16 .007	18
	2nd		Omitted	Tree run	2000	0	8/7 .074	
	3rd	6/17	The same as 1st cover				9/5 .060	
	4th		Omitted				10/15 .046	
	5th	7/24	The same as 1st cover					
3	1st	5/22	1 qt. D-X,[2] 3 lbs. lead, 3 lbs. lime	Ground	1131	5	No	32
				Tree run	2000	0	Analysis	
	2nd	6/4	The same as 1st cover					
	3rd	6/17	The same as 1st cover					
	4th	7/1	The same as 1st cover					
	5th	7/24	The same as 1st cover					
4	1st	5/22	3 lbs. lead, 3 lbs. lime	Ground	1201	11	Pb. Gr./Lb.	47
	2nd	6/4	The same as 1st cover	Tree run	2000	8	7/16 .160	
	3rd	6/17	The same as 1st cover				8/7 .180	
	4th	7/1	The same as 1st cover				9/5 .060	
	5th	7/24	The same as 1st cover				10/15 .060	
5	1st	5/22	1 qt. 30% DDT emulsion	Ground	1428	66	7/16 .059	23
	2nd	6/4	The same as 1st cover	Tree run	2000	20	8/7 .042	
	3rd	6/17	The same as 1st cover				9/5 .038	
							10/15 .024	
6	1st	5/22	1 lb. DDT	Ground	1256	1	7/16 .131	18
	2nd	6/4	12 oz. DDT, 3 qts. oil	Tree run	2000	0	8/7 .092	
	3rd	6/17	1 lb. DDT, 3 qts. oil				9/5 .082	
	4th	7/1	The same as 2nd cover				10/15 .068	
	5th	7/24	The same as 2nd cover					
7	1st	5/22	1 lb. DDT	Ground	1711	23	7/16 .077	15
	2nd	6/4	12 oz. DDT, 20 ozs. DN-111	Tree run	2000	0	8/7 .088	
	3rd	6/17	The same as 1st cover				9/5 .070	
	4th	7/1	The same as 2nd cover				10/15 .050	
	5th	7/24	12 oz. DDT					

Table 1.—(Continued)

PLOT	COVER	DATE	SPRAY MATERIALS PER 100 GALLONS OF WATER	APPLES EXAMINED		WORMS	DDT GR./LB. COL. DIFFERENT DATES		AVERAGE NO. RED MITE PER LEAF
8	1st	5/22	3 lbs. benzene hexachloride, 1 qt. spreader[1]	Ground Tree run	1821 2000	461 135	No Analysis		19
	2nd	6/4	The same as 1st cover						
	3rd	6/17	The same as 1st cover						
	4th	7/1	The same as 1st cover						
	5th	7/24	The same as 1st cover						
9	1st	5/22	1 qt. 25% DDT emulsion, 3 lbs. lead, 3 lbs. lime	Ground Tree run	1187 2000	7 0		Pb. Grs./Lb.	26
	2nd	6/4	The same as 1st cover				7/16	.043 .016	
	3rd	6/17	The same as 1st cover				8/7	.064 .200	
	4th	7/1	The same as 1st cover				9/5	.042 .070	
	5th	7/24	The same as 1st cover				10/15	.032 .040	
10	1st	5/22	1 lb. DDT	Ground	1247	9	7/16	.113	28
	2nd	6/4	12 oz. DDT	Tree run	2000	0	8/7	.051	
	3rd	6/17	The same as 1st cover				9/5	.038	
							10/15	.032	
11	1st	5/22	2 lbs. DDT	Ground	1154	0	7/16	.019	13
	2nd		Omitted	Tree run	2000	0	8/7	.124	
	3rd	6/17	2 lbs. DDT, 3 qts. oil				9/5	.110	
	4th		Omitted				10/15	.086	
	5th	7/24	The same as 3rd cover						
12	1st	5/22	1 lb. DDT	Ground	903	0	7/16	.085	45
	2nd	6/4	12 oz. DDT	Tree run	2000	0	8/7	.074	
	3rd	6/17	The same as 1st cover				9/5	.064	
	4th	7/1	The same as 2nd cover				10/15	.056	
	5th	7/24	The same as 2nd cover						
13	1st	5/22	2 lbs. DDT	Ground	1223	2	7/16	.074	15
	2nd	6/4	Omitted	Tree run	2000	0	8/7	.102	
	3rd	6/17	The same as 1st cover				9/5	.064	
	4th	7/1	Omitted				10/15	.056	
	5th	7/24	The same as 1st cover						
14	1st	5/22	1 lb. DDT	Ground	872	48	7/16	.085	31
	2nd	6/4	12 oz. DDT, 3 qts. oil	Tree run	2000	0	8/7	.092	
	3rd	6/17	1 lb. DDT, 3 qts. oil				9/5	.070	
	4th	7/1	The same as 2nd cover				10/15	.064	
	5th	7/24	The same as 2nd cover						
15	1st	5/22	1 qt. DDT emulsion	Ground	1187	30	7/16	.063	24
	2nd	6/4	The same as 1st cover	Tree run	2000	4	8/7	.063	
	3rd	6/17	The same as 1st cover				9/5	.050	
	4th	7/1	The same as 1st cover				10/15	.034	
	5th	7/24	The same as 1st cover						
16	1st	5/22	1 lb. DDT	Ground	1846	49	7/16	.060	34
	2nd	6/4	12 oz. DDT	Tree run	2000	4	8/7	.070	
	3rd	6/17	1 lb. DDT, 20 oz. DN-111				9/5	.056	
							10/15	.042	
	4th	7/1	The same as 2nd cover						
	5th	7/24	12 oz. DDT, 20 oz. DN-111						

[1] *Orthex.* [2] *D-X* a commercial spray containing 5% DDT plus rotenone and pyrethrins.

The large number of samples involved makes it impractical to show all the data obtained.

DISCUSSION.—All of the spray formulations, except benzene hexachloride, gave excellent codling moth control. Fruit from seven of the plots showed excessive residue at harvest with the three plots receiving oil running highest. The addition of oil to DDT increased the residue, but failed to show an increase in control.

Three applications of DDT at 1 pound in the first cover and 12 ounces in the second and third covers gave as good control as where five applications were used. DDT wettable powder and DDT emulsion when used at double the recommended strengths and applied at approximately 25 day intervals, gave excellent control, but the two plots treated with powder showed excessive residue at harvest. Five applications of benzene hexachloride failed to give satisfactory control of codling moth when used alone.

All combinations of oil and DDT, benzene hexachloride alone and combined with DDT and the double strength DDT emulsion, resulted in poor foliage throughout the season and poor finish on fruit at harvest. Bordeaux mixture was combined with one or more sprays on all plots and probably attributed to poor foliage and poor finish on the fruit.

The data obtained on the control of European red mite indicate that any of the formulations used would have failed to give satisfactory control in a season favorable to red mite development. Contrary to expectations the highest population was found on the plot treated with lead arsenate without the addition of a mite killing ingredient.

The spray deposit on foliage varied during the season from 6.9 grains per pound from one sample in plot 5 to 31 grains per pound from a sample collected on the same date in plot 11. The lowest average residue for the season was in plot 5 with 6.25 grains per pound of foliage, and the highest average deposit was in plot 12 with 16.08 grains per pound of foliage. The deposit on plot 5 was not sufficient to prevent codling moth worms from entering the fruit. The ground apples showed 4.6 worms and the tree run apples one worm per each 100 apples. Plot 12

had 100-per cent clean fruit. Other plots with a much lower residue than we found on plot 12 showed only a fraction of a per cent of worms.

No definite conclusions can be drawn from one season's record on the amount of DDT deposit necessary on foliage for good control of codling moth. The data from the analyses of 360 samples of foliage correlated with codling moth control, indicate, however, that foliage collected on August 15 should contain approximately 8 grains of DDT per pound. The data further indicate that the deposit should never fall below 3 grains per pound from the first application of DDT until worm activity has ceased.

CONCLUSION.—The data obtained on codling moth control showed clearly that in years unfavorable for codling moth development good control can be obtained with any of the standard recommended sprays, if the applications are timely and thorough.

Three applications of DDT wettable powder, using standard recommendations, and three applications at double strength, and applied at 25 day intervals, all gave excellent control of codling moth. However, the double strength applications caused excessive residue at harvest.

The red mite population never developed to a serious status on any of the plots. The addition of dinitro compounds,[1] oil or any other material to the spray, failed to give satisfactory control.

Analyses of 360 samples of foliage collected at different intervals during the season indicate that, in order to secure satisfactory control of codling moth, it should contain approximately 8 grains of DDT per pound of foliage on August 15, and that the deposit should never fall below 3 grains per pound after the first application of DDT is made.

[1] *DN-111.*

Gamma-Benzene Hexachloride in the Liquefied-Gas Aerosol[1]

J. H. FALES, E. R. MCGOVRAN, and R. A. FULTON,
U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine

A commercially prepared product containing 100 per cent of gamma-benzene hexachloride was substituted for DDT in the pyrethrum-DDT aerosol formula and tested in a Peet-Grady chamber against house flies, *Musca domestica* L., and mosquitoes, *Anopheles quadrimaculatus* Say. This product had a less objectionable odor than samples used in previous experiments with this aerosol formula (McGovran, Fales, and Goodhue 1946).

Two series of tests were made on separate formulations. The aerosol was delivered into the chamber by a swinging-shutter methoe recently described by McGovran and Fales (1947). The free-flying insects were exposed for 15 minutes, and mortality counts were made after 1 day.

In series 1 the formula containing pyrethrins 0.4 per cent, DDT 3 per cent, and diisopropylnaphthalene (a commercial product designated as K-294) 17 per cent was compared with one containing gamma-benzene hexachloride 2 per cent and diisopropylnaphthalene 15 per cent. The propellent gas was Freon-12 (dichlorodifluoromethane) in both cases. At equal dosages of 0.40 gram of aerosol solution per 1000 cubic feet, the benzene hexachloride formula killed 70 per cent of the house flies and the DDT formula 59 per cent. The kill of female mosquitoes was also greater with the benzene hexachloride, 89 per cent as compared with 74 per cent with DDT. The benzene hexachloride formula caused a greater knockdown of both flies and mosquitoes.

In series 2 gamma-benzene hexachloride was substituted for DDT in the standard cyclohexanone-lubricating oil formula—pyrethrins 0.4, DDT 3, cyclohexanone 5, and lubricating oil 5 per cent. The benzene hexachloride formula killed 80 per cent of the house flies and the DDT formula 58 per cent at similar dosages (0.42 and 0.43 gram per 1000 cubic feet). The kill of mosquitoes was also greater—96 per cent against 74 per cent for females, and 98 per cent against 74 per cent for males. The 15-minute knockdown of house flies was 49 per cent against 21 per cent for the DDT formula. The mosquito knockdown was also markedly greater.

The addition of DDT to the pyrethrum aerosol increased the effectiveness against house flies roughly 10 times. The results shown here indicate that the use of gamma benzene hexachloride would further increase the effectiveness in kill and knockdown against both houseflies and mosquitoes.

Gamma-benzene hexachloride caused no corrosion of metal in the standard aerosol corrosion test. —5-2-47.

[1] This research was conducted as part of a program supported by a transfer of funds from the Office of the Quartermaster General, U. S. Army, to the Bureau of Entomology and Plant Quarantine.

LITERATURE CITED

McGovran, E. R., J. H. Fales, and L. D. Goodhue. 1946. New formulations of aerosols dispersed by liquefied gases. JOUR. ECON. ENT., 39(2): 216–9.

McGovran, E. R., and J. H. Fales. 1947. Swinging-shutter apparatus for measuring small dosages of insecticidal aerosol. U.S.D.A. Bur. Ent. and Plant Quar. ET-239.

Blue Oat Mite Damage to Wheat in Utah

GEORGE F. KNOWLTON, *Utah Agricultural Experiment Station, Logan*

The blue oat or pea mite, *Penthaleus major* (Duges), family Penthaleidae, was collected on different dates during March, 1947, from a field of fall irrigated wheat at Hunter, Utah, in Salt Lake County. This crop was being seriously damaged.

The affected field consisted of 18.4 acres divided into three east-west strips. Two strips were of fall irrigated wheat. The third strip, on the north, was clean cultivated and had been planted to spring wheat. The owner of this land is a poultry raiser who normally raises 15,000 to 18,000 chickens per year. The manure has been used to fertilize this farm once a year.

The south strip of fall wheat, consisting of 8 acres, had been well fertilized twice, at yearly intervals. This strip showed approximately an acre in which the wheat plants were severely damaged by March 12 to 27. Wheat in much of this area had been killed out or was badly yellowed, due to mite injury. Most of the wheat of both strips was very heavily infested by mites, which were present in numbers on foliage. The mites were so numerous as to give a dark bluish red color to spaces between mite-injured sheaths where the thickly planted wheat stems grew closely packed together. The soil around the roots often was dark bluish red when injured wheat was

pulled, due to the great numbers of mites. Many roots were not normal, probably having sustained mite injury. Leaf injury generally was less severe than sheath injury.

Examination of nearby fields of fall irrigated and dry farm wheat, and a number of wheat fields between Salt Lake and Magna, failed to show equally heavy infestation. However mites were encountered in various other fields within one to three miles of the most severely damaged field. Mites were much less abundant, and less seriously injured wheat plants had largely recovered by mid-April, in the most seriously injured field. By May 16, mites were scarce and the surviving wheat was of good color.

In addition to identifying the injurious mite as *P. major*, Dr. E. W. Baker of the United States Bureau of Entomology and Plant Quarantine found the three predaceous mites, *Hypoaspis* sp., *Parasitus* sp. and *Typhlodromus* sp. also present among material collected in the most seriously damaged field at Hunter. In addition the mite, *Diphaulocylliba* sp. was found.—6-2-47.

Small Dispensers for Larviciding in Mosquito Control[1]

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Since World War II the procurement and holding of labor has been one of the biggest problems in mosquito work. Most men are no longer willing to carry knapsack sprayers and other large sprayers, or to endure the burning and discomfort due to oil spilled on the skin. The advent of DDT and new spreaders has made it possible to obtain effective control with small amounts of material. A new applicator has been adapted to larviciding operations in Morris County, New Jersey, replacing the older type hand-spraying equipment. The dispenser is small and the method of application is simple.

THE DISPENSER.—Some years ago an effective control was developed for corn ear worm by using a small force oiler to oil the silks. This same applicator (the Eagle Force Oiler) has been found the most satisfactory for application of mosquito larvicide. The dispenser of about 100 ml. capacity puts out about 1 ml. of oil per stroke for a distance of 20 to 30 feet. For small areas the oiler alone makes an ideal piece of equipment, and for larger areas the capacity can be increased by attaching a 1 gallon can to the oiler with a piece of rubber tubing. The can is then carried on the back as is done in corn earworm control. Enough material can be carried in this manner for treatment of several acres.

MATERIAL.—Various concentrations of DDT, fuel oil and spreaders were tested and a definite formulation has been selected which has given the best results in actual control operations. This mixture consists of 1.5% DDT and .5% B1956 emulsifier (Rohm & Haas) in No. 2 fuel oil. This formulation was applied at the rate of 1 ml. per 50, 100 and 200 sq. ft. (½, 1 and 2 pints per acre), and in all cases 100% kill of the larvae was noted. Kills resulted within 24 hours where 1 ml. was applied to 50 sq. ft. However, in some cases 72 hours were necessary to obtain complete kills when 1 ml. was applied to 200 sq. ft. of surface area. The concentrations of this material are so small that even if an over-dose is applied, not enough DDT is present to affect aquatic life adversely, or to obtain a residual of DDT. Control of pupae is not possible with such small amounts of DDT. In the application of this material the writer aimed to kill all larvae present, but not to obtain a residual effect.

The small disperser and larvicide described above are now being used in Morris County, New Jersey in the regular mosquito control program. The use of heavy hand equipment and the application of large amounts of oil to the acre for control of mosquito larvae have thus been eliminated. At the same time the cost of materials and labor have been reduced materially. Extensive tests are now in progress with various materials as possible larvicides.—7-7-47.

[1] A paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University.

A Separator for Onion Thrips[1]

J. L. HOERNER, *Colorado Experiment Station, Fort Collins*

In 1945, onion thrips control studies were started at the Colorado Potato Experiment Station, Greeley, Colorado, in cooperation with W. C. Edmundson, U.S.D.A. In addition to yield data, thrips counts were made to help in determining the effectiveness of insecticides. The number of thrips was determined in the field on 10 half-plants by spreading apart the leaves on one side of the plant and counting the thrips on the leaves to the center of the plant. This method proved to be laborious and not accurate.

At the suggestion of Dr. James R. Douglass, Bureau of Entomology and Plant Quarantine, Twin Falls, Idaho, the method of counting thrips was improved for the 1946 season. The tops of 10 onion plants from a plot were placed in a container over a modified Berlese funnel and heated in a temperature cabinet at 116°F. for 5 hours. At the end of the heating period, all the thrips were in a shell vial of 70 percent alcohol beneath the funnel. The thrips were then counted under a binocular microscope.

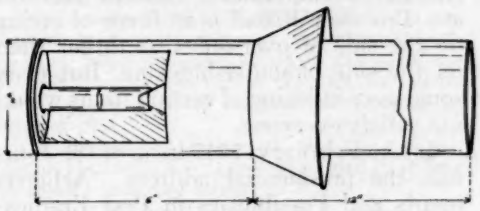

FIG. 1.—Separator for onion thrips.

The funnel was made by cutting the tip from a 14 ounce soda cup and cementing the cup to a 6 inch base of a 3 inch cardboard mailing tube. The base of the mailing tube was cut away to permit the insertion of a 1½ dram shell vial underneath the funnel. A 12×3 inch mailing tube was used to support the onion plants over the funnel. The complete assembly is shown in the accompanying diagram.

The apparatus worked perfectly, except that the 3-inch containers were not quite large enough to hold the tops of 10 onion plants late in the season. Four inch containers will be used another year.

[1] Scientific Series Paper 252, Colorado Agricultural Experiment Station.

JOURNAL OF ECONOMIC ENTOMOLOGY
Official Organ American Association of Economic Entomologists

Vol. 40 October, 1947 No. 5

INDEXING THE JOURNAL

In the February, 1947 issue of the JOURNAL OF ECONOMIC ENTOMOLOGY Prof. Theodore L. Bissell in an editorial entitled "Keeping Up With The Literature" stresses the need of up-to-date entomological indexes and calls attention of omissions in the index published each year in the December issue of the JOURNAL OF ECONOMIC ENTOMOLOGY. I am in theoretical agreement with the ideas of that editorial but from a practical standpoint, there are obstacles which are difficult to overcome.

An indexer never completely satisfies all the users of an index and in making an index it is difficult to know where to draw the line. The index in the December Journal does not claim to be more than a general index, mainly to the titles of papers in the current volume. It is purposely restricted because of the more expanded indexing that the papers receive in the Colcord Index, Biological Abstracts, Experiment Station Record, etc. Professor Bissell is in favor of erring on the side of over-indexing rather than on the side of under-indexing. But even some over-indexing of certain items would not satisfy everyone.

In the February, 1947 issue of the Journal, the presidential address, "Achievements and Possibilities in Pest Eradication" ordinarily would have two entries such as "Pest eradication, possibilities in" and "Eradication, pest, possibilities in." However this address contains references to some 45 insects, with common and scientific names. Should these be indexed there would be 90 additional entries instead of the original two. Again, the article, page 9 of the February, 1947 issue entitled "Effect of Artificial Control Practices on the Parasites and Predators of the Codling Moth" would normally have four entries, as follows, "*Carpocapsa pomonella*," "Codling moth, effect of control practices on parasites and predators of," "Parasites of codling moth, effect of control practices on," "Predators of codling moth, effect of control practices on." However the body of this paper contains mention of more than 100 parasitic and predaceous species. Should these be indexed, bringing the entries to 104 rather than four? The article "Hosts and Distribution of *Anastrepha serpentina*," February, 1947 issue page 34 of the Journal would normally have one entry, such as "*Anastrepha serpentina*, hosts and distribution of." Yet this paper includes mention of more than 30 hosts, which if indexed would mean 30 extra lines of printing, to say nothing of the extra work involved in making index slips. Finally one runs up against the same thing in indexing the names of insecticides. The article entitled "The Permanence of Termite Repellents," February, 1947 issue, page 124, would ordinarily have two entries, but if the names of the repellents were included, the entries would number over 50.

These are not unusual examples. Almost every paper in every issue of the Journal could be indexed in an exhaustive manner. If this were done it might still fail to meet the requirements of every index user. Our entomological publications contain thousands of observations that are never mentioned in indexes, because the titles of the papers fail to describe the contents adequately. In many cases such descriptions would be impossible in titles. I realize the desirability of perfection in indexes and of the time that could be saved if one could depend entirely upon an index for a true description of contents. But indexes are simply clues, good or bad depending in part on the special needs of the investigator.

I would like to see the index to the Journal improved if it is not meeting the

needs of the subscribers in its present form, provided one keeps in mind the fact that the expanded Colcord Index will probably be issued in the near future on a yearly basis. There is no fun in making an index, but at the least it should be faithfully done to meet the general need. The great difficulty is in determining what should be taken from the body of an article and what should be left out, keeping in mind the varied needs of entomologists in general. H. B. W.

NOTE

Chemical-Biological Coordination Center

During the war, the Office of Scientific Research and Development created a committee to deal with problems of insect and rodent control. This committee subsequently came under the direction of the National Research Council and continued to act as a center for the correlation of activities in these two fields. It soon became evident that information, particularly on the biological action of chemicals, could be of importance to other fields of research. Consequently, it seemed desirable to broaden the scope of the Insect and Rodent Control Committee and continue its activity beyond the end of the war.

For this purpose, the Chemical-Biological Coordination Center of the National Research Council was organized in July, 1946. Subcommittees were formed to deal with each aspect of the Center's program. The members of the Entomology Subcommittee are:

R. B. Friend, Connecticut Agr. Expt. Sta., *Chairman*
F. C. Bishopp, U.S.D.A., Washington
D. Bodenstein, Army Chem. Center, Edgewood Arsenal
A. M. Boyce, University of California
R. L. Patton, Cornell University
J. F. Yeager, U.S.D.A., Beltsville, Md.

The Coordination Center had two main objectives: to assemble and organize information which correlates the structure of chemicals with their biological activity and to sponsor the preliminary testing of chemicals to determine the biological effects of the compounds.

The Center is soliciting chemicals from individual investigators, institutions and business organizations. Many of the chemicals are recently-synthesized compounds; many others have been accumulating for years. The Center receives these, together with available chemical data, and distributes samples to approved laboratories which are equipped to conduct screening experiments. Any compound may thus be tested for its insecticidal or other value. Results of the experiments are to be reported to the Center which, in turn, will transmit them to the person who donated the compound. Thus the Center will act as a medium of cooperation between those who synthesize compounds and those who investigate their action.

The primary objective of the Center is not only to provide the means for assembling and organizing information on chemicals and their biological activity but to make this information available to investigators. It is hoped that, ultimately, entomologists may secure, upon request, a great deal of material which will be of use in their research.

To establish a form in which this material may be readily accessible, a punched card filing system is being developed. Reports of screening tests and abstracts of all published papers will be added to the file. Many compounds will be found to be relatively ineffective and be discarded. Such results may not be published by the investigator. But knowledge of these compounds and of their action would eliminate much duplication of effort and would facilitate the orientation of any new research which was contemplated. Moreover, chemicals which were found to have no value for entomologists might still be useful in other fields.

At this time the Entomology Subcommittee is anxious to enlist the cooperation of all research entomologists. It would be glad to receive reprints of published research. In addition, it would like data on unpublished work and will send out forms on which such data can be recorded. All of this material will be incorporated into the files for the use of any research worker. In this way, entomologists can make an important contribution to the usefulness and efficiency of the Center. The Center, on its part, will make all of its facilities available to entomologists.

The Research Associate at the Coordination Center, Dr. Helen W. Kaan, will be glad to answer questions which may arise.